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ABLATION AND RADIATION COUPLED VISCOUS HYPERSONIC SHOCK LAYERS

VOLUME II

by

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APPENDIX C

LRAD 3 COMPUTER PROGRAM

DISCUSSION OF THE PROGRAM

This appendix describes a computer program which can be used to determine the radiative flux and flux divergence through a noniso-thermal planar slab of gas. The program considers species typical of air at high temperatures and nylon or carbon phenolic ablation products. The equations solved are for a variable optical depth line and continuum gas model using species cross sections and line widths as the basic data.

The detailed radiation model used in the present work is a coupled line and continuum model developed by Wilson (Ref. C.1). The computer program used in the present analysis is called LRAD 3 and is a modified version of Wilson's subroutine TRANS. LRAD 3 consists of a driver program and a set of subroutines which are for the most part subsets of subroutine TRANS. By providing a driver program and breaking TRANS into a set of subroutines greater flexability and reduced computation time was achieved.

The program LRAD 3 provides a useful tool for evaluating the radiative flux and flux divergence across a slab of gas containing both air and ablation species. The program can be used in subroutine form in conjunction with a flow-field program or independently for parametric studies. Twelve continuum and nine line frequency bands are used in the radiation calculation. Radiation properties for the following species are included:

$$\left.\begin{array}{c}H\\ C\\ O\\ N\end{array}\right\}\text{Line and Continuum}\qquad\qquad \left.\begin{array}{cc}CO & O_2\\ C_2 & N_2\\ C_3 & H_2\\ C_2H & \end{array}\right\}\text{Continuum}$$

The computational techniques and equations solved are presented in detail in Appendix B. The radiation model and species considered were developed as a compromise between detail of computation (computer time) and accuracy. The accuracy of the line and continuum calculation for the four atomic species was found to be quite good by Wilson (Ref. C.1) by comparison with a more detailed radiation program RATRAP.

INPUT GUIDE

All inputs to the radiative transfer computer program (LRAD 3) are read from cards: no tapes are required. The basic inputs consist of (1) temperature: (2) number densities or mole fractions, density and average molecular weight: (3) shock layer coordinates: (4) input option parameters; and (5) a set of shock layer points used in the integration to obtain the flux. Three basic formats are used for input, I5, E12.0 and A4. The I5 is an integer format consisting of five (5) columns right adjusted, the E12.0 is a floating point format occupying twelve (12) columns with a decimal point punched on the card, and A4 is an alphabetic format. Multiple cases may be run by placing the input data for each new case behind the data for the previous one.

Tab. C.1 provides the details of the card input and Tab. C.2 gives the meanings of the input variables.

TABLE C.1

CARD INPUT FOR LRAD 3

CARD TYPE	Variables	Format
1	TIT (I)	20A4
2	NETA, MF, NS, LINES, IDG, IEZ	6I5
3	R, DELTA, DTIL, XMØL, RDZ	5E12.0
4	T (I)	6E12.0
5	YD (I)	6E12.0
6	ETA (I)	6E12.0
7	INDEX	6I5
8A*	DENS (K, INDEX)	6E12.0
8B*	FRAC (K, INDEX)	6E12.0
9°	ETZ (I)	6E12.0
10+	RHØ (I)	6E12.0
11+	AMW (I)	6E12.0

* Either Card 8A for number densities or Card 8B for mole fractions is read but not both.

+ If Card 8A is read, Cards 10 and 11 are not read. If Card 8B is read both Cards 10 and 11 are read.

° If IEZ = 0 Card 9 is not read.

TABLE C.2

VARIABLE DEFINITIONS FOR LRAD 3

Variable	Description
TIT	Title for identification of the problem.
NETA	The number of points used in the slab calculation.
MF	Species concentration option variable. MF=1 Mole fractions are input on Card 8B and number densities are computed. MF=0 Specie number densities are input on Card 8A.
NS	The number of species to be input.
LINES	Line radiation option variable. LINES=0 Only a continuum calculation is done. =1 A coupled line-continuum calculation is done.
IDG	A switch to allow intermediate printout. IDG=0 Only finial results are printed. =1 Print at each ETA is given. =2 Complete print is given.
IEZ	The number of points used in the flux integration. IEZ=0 The ETA array will be used for the ETZ array. 0<IEZ<NETA Specifies the number of points in the ETZ array. Card 9 will be read.
R	Body radius (ft.)
DELTA	Nondimensional stand-off distance (δ/R)
DTIL	Transformed stand-off distance ($\tilde{\delta}$)
XMØL	A molecular radiation option switch. XMØL=0 Molecules not included in the radiation calculation. =1.0 Molecules included in the radiation calculation.
RDZ	The density directly behind the shock. ($\rho_{\delta,0}$; lbm/ft^3)
T(I),I=1,NETA	The temperature profile across the shock layer. (^{o}K)

TABLE C.2 (Cont.)

YD (I),I=1,NETA	The nondimensional shock layer location where temperature, concentration etc. are given. (y/δ)
ETA(I),I=1,NETA	The Dorodnitzyn transformed shock layer locations corresponding to the y/δ locations. (η)
INDEX	The number given each specie for use in storing arrays. This permits species to be read in any order and is placed before each set of cards of type 8A or 8B. INDEX = 1 = Ø2 7 = H 2 = N2 8 = C2 3 = Ø 9 = H2 4 = N 10 = CØ 5 = E- 11 = C3 6 = C 12 = C2H
DENS(K,INDEX) K=1,NETA	Species number densities. (particles/cm^3)
FRAC(K,INDEX) K=1,NETA	Species mole fractions.
ETZ(I),I=1,IEZ	A subset of ETA points used in the flux integration. If IEZ=0 the ETZ points will automatically be set equal to the ETA(I) points.
RHØ(I),I=1,NETA	Nondimensional density profile across the shock layer. $(\rho/\rho_{\delta,0})$
AMW(I),I=1,NETA	The average molecular weight profile across the shock layer.

The species considered in the program will probably be a subset of the species considered in a shock layer flow-field. Only those twelve species listed with an INDEX number can be input. If the field of interest is ionized, the input of electron concentrations is necessary, although ionic species are not input.

The subset of ETA points, the ETZ points, used in the flux integration calculation should be carefully chosen. The purpose of using a subset of ETA points is reflected in the required computation time (i.e. 5 minutes for 60 ETZ = ETA points and 2.5 minutes for 30 ETZ points where NETA = 60). The computation times cited are for a IBM 360-65. To maintain accuracy keep ETA points as ETZ points in regions where either concentration or the temperature is varying rapidly.

OUTPUT DESCRIPTION

This section presents a description of the LRAD 3 program output format and definition of output symbols. The reader may find it instructive to refer to the listing of the sample problem while reading this section.

The first four pages of output are a print of the input data. This is provided so that the user can check the input for possible errors, and it also provides identification of the problem. All quantities on these pages are defined in the input guide section. The concentrations printed on pages 3 and 4 are either number densities or mole fractions depending on the option used for input purposes. The difference is easily distinguishable by the magnitude of the numbers. These concentrations are followed by the shock thickness DELTA in cm.

The standard output shown (i.e. IDG=0) provides a print of the specie number densities on pages 5 and 6. The results of the radiation calculation are printed on the seventh page of output. The continuum contribution and the line contribution to the spectral flux are printed for three ETA points (ETA=0.0=wall, ETA=0.5, ETA=1.0=shock) as a function of frequency interval HNU=$h\nu$. The columns of fluxes in watts/cm^2 denoted by QPLUS and QMINUS designate fluxes to the surface and away from the surface respectively. The total radiative flux at the three ETA locations stated above are printed in watts/cm^2. The number on the left can be interpreted as the radiative heating to the surface.

SAMPLE PROBLEM AND PROGRAM LISTING

The following example is presented to illustrate the basic input for the LRAD 3 program and to show a typical output listing. The example considered is typical of stagnation line shock layers in that the temperature and species compositions change from surface to post shock values. All twelve possible species are included in the example. The integration is carried out over 59 ETA=ETZ points and thus card-type 9 is not input. Furthermore, species number densities are input on card type 8A and thus card type 10 and 11 are not required in addition to RDZ on card type 3.

The required input data for this example are listed on the following pages. After the input a listing of the output for the example is given. Finally a listing of the LRAD 3 program is provided.

```
SAMPLE CASE FOR LRAD 3
  59    0   12    1    C    0
 C.9CCC0E 01 C.5C750E-01 0.1301CE 00 0.1C0CCE 01
 C.34502E C4 C.34527E 04 0.34560E 04 0.34593E 04 0.34643E 04 0.34697E 04
 C.34783E C4 C.34890E 04 C.35053E 04 0.35267E 04 0.35560E 04 0.3575CE C4
 0.36CC0E 04 0.363CCE 04 0.36677E 04 0.37147E 04 0.37743E 04 0.3847CE 04
 0.39434E 04 C.40731E 04 0.41690E 04 0.43029E 04 0.44341E 04 0.46086E 04
 C.48375E C4 C.51314E 04 0.53915E 04 0.57283E 04 0.60847E 04 0.63853E C4
 0.67279E C4 0.69823E 04 C.72994E 04 C.77285E 04 0.82026E 04 0.86295E C4
 C.94914E C4 C.99762E 04 C.10232E 05 C.1C573E 05 C.10787E 05 0.10849E 05
 0.11270E 05 0.11885E 05 C.12090E C5 C.12251E 05 C.12419E 05 C.12571E 05
 C.12728E C5 C.12862E 05 0.12997E 05 0.13122E 05 0.13248E 05 0.13373E 05
 0.13506E C5 C.13638E C5 C.13839E 05 0.1404CE 05 0.14373E 05
 C.0         0.1576CE-01 C.31540E-C1 C.4736CE-01 0.63230E-01 0.7916CE-01
 C.95180E-01 C.1113CE 0C 0.1276CE 0C 0.14410E 00 0.16090E 00 0.1695CE 00
 C.17820E 00 C.1871CE 00 C.19620E 00 0.2C560E 00 0.21530E 00 0.2256CE 0C
 C.23660E CC 0.2485CE 00 C.25500E 0C C.26060E C0 0.26370E 00 0.2662CE CC
 C.26860E C0 0.2712CE 0C C.2735CE CC 0.276CCE 00 0.27860E 00 0.2814CE 00
 0.28440E 00 C.2876CE 0C 0.29C90E 00 0.29430E C0 0.29800E 00 0.3018CE 00
 0.312C0E C0 0.32240E 00 C.33240E 00 0.342C0E 00 0.35970E 0C 0.3754CE CC
 0.39C40E CC 0.42C9CE CC C.45230E C0 0.48480E 00 0.51830E 00 0.5527CE CC
 0.58810E C0 0.6245CE CC 0.66200E C0 0.70050E 00 0.73980E 00 0.78C1CE 00
 0.82150E C0 0.86390E 00 0.9C710E 0C 0.95210E C0 0.100C0E 01
 C.0         0.4CC0CE-01 0.8CC0CE-01 0.12C0CE 00 0.160C0E 00 0.2000CE 0C
 0.24C00E 00 C.28C00E 0C 0.3200CE 00 C.36C0CE 00 0.40000E 00 0.42CCCE CC
 C.44CCCE CC 0.46CCCE CC C.48C00E 00 0.5C00CE 00 0.52000E 00 0.540CCE 0C
 0.56CC0E 00 0.58CCCE 00 0.59C00E 00 C.5980CE 00 0.60200E 00 0.6050CE 00
 0.60750E CC 0.61C00E 00 C.6120CE C0 0.614CCE 00 0.616CCE 00 0.618CCE CC
 0.62CC0E CC 0.62200E 00 C.62400E CC 0.6263CE C0 C.628CCE 00 0.63CCCE 0C
 C.635C0E C0 0.64CCCE 00 0.6450CE 00 0.65000E 00 0.660C0E 00 0.67CCCE 00
 0.68CC0E 00 0.7CCCCE 00 0.72C0CE 00 0.740CCE C0 0.760C0E 00 0.78C0CE CC
 0.8CCC0E C0 C.82000E 00 0.84C00E 0C C.86CCCE 00 0.88000E 00 0.9000CE 00
 0.92C00E CC C.94C0CE C0 0.9600CE 0C C.98CC0E 00 0.100C0E C1
   1  02
 0.60163E C4 C.60120E 04 0.60062E 04 0.6CCC4E 04 0.59917E 04 0.59825E 04
 0.59676E C4 C.59494E 04 C.91284E 04 0.9C731E 04 0.69680E 04 0.6931CE C4
```

```
C.68828E 04 0.11069E 05 0.10955E 05 0.22047E 05 0.29825E 05 0.38683E 05
0.32363E 05 C.1C305E 06 C.15430E 06 C.29354E 06 0.56852E 06 0.89916E C6
C.38912E C7 0.45078E 08 0.24319E C9 C.18269E 10 0.11435E 11 0.3848CE 11
C.93160E 11 C.12749E 12 0.17615E 12 0.14789E 12 0.10216E 12 0.71421E 11
C.38467E 11 0.34972E 11 0.46086E 11 0.55411E 11 0.76806E 11 0.87654E 11
C.7CCC2E 11 C.45488E 11 0.38627E 11 0.33903E 11 0.29521E 11 0.25982E 11
C.22721E 11 C.20218E 11 0.17951E 11 0.16046E 11 0.14299E 11 0.1273CE 11
C.11235E 11 0.99022E 10 0.81013E 10 0.66033E 10 0.46421E 10
  2  N2
C.1C283E 17 C.1C275E 17 0.1C265E 17 0.10255E 17 0.1024CE 17 0.10225E 17
C.10199E 17 0.1C168E 17 C.96066E 16 C.95484E 16 0.89665E 16 0.89188E 16
0.88569E 16 0.8C388E 16 0.79562E 16 0.7C029E 16 0.63011E 16 0.5525CE 16
C.459C4E 16 0.3577CE 16 0.30C91E 16 0.24462E 16 0.21136E 16 0.19259E 16
0.19749E 16 C.22305E 16 C.23287E 16 0.2CC10E 16 0.12818E 16 0.7295CE 15
C.33897E 15 C.18939E 15 C.94079E 14 0.37613E 14 0.15353E 14 0.76964E 13
C.30516E 13 0.68338E 13 0.33443E 14 C.709C2E 14 0.12719E 15 0.13648E 15
0.82820E 14 C.3693CE 14 0.27759E 14 0.22146E 14 0.17455E 14 0.14035E 14
C.11178E 14 C.91805E 13 0.75218E 13 0.62394E 13 0.51559E 13 0.42582E 13
C.34719E 13 C.28283E 13 0.2048CE 13 C.14795E 13 0.85271E 12
  3  O
C.74492E 11 C.74438E 11 0.74366E 11 0.74295E 11 0.74187E 11 0.74073E 11
C.73889E 11 C.73663E 11 C.96284E 11 0.95701E 11 0.12250E 12 0.12185E 12
C.121C0E 12 0.17C71E 12 0.16895E 12 0.24471E 12 0.31480E 12 0.42339E 12
0.62C97E 12 0.1C297E 13 0.14953E 13 0.25358E 13 0.43234E 13 0.9046CE 13
C.24898E 14 0.91632E 14 C.27897E 15 0.1C387E 16 0.34680E 16 0.78928E 16
C.15316E 17 0.20785E 17 C.24654E 17 0.27787E 17 0.28252E 17 0.27751E 17
C.26889E 17 0.29283E 17 0.35858E 17 0.42617E 17 0.52637E 17 0.57C0CE 17
0.55578E 17 C.5C235E 17 0.47952E 17 0.46144E 17 0.44242E 17 0.42511E 17
C.40721E 17 C.3919CE 17 C.37658E 17 0.36242E 17 0.34819E 17 0.33418E 17
0.31952E 17 C.3C512E 17 C.28322E 17 C.26209E 17 0.22857E 17
  4  N
C.257C6E 14 C.25687E 14 0.25662E 14 0.25637E 14 0.25600E 14 0.25561E 14
0.25497E 14 C.25419E 14 0.31966E 14 0.31772E 14 0.39021E 14 0.38813E 14
C.38544E 14 C.51079E 14 0.5C554E 14 0.67769E 14 0.81890E 14 0.10169E 15
C.13264E 15 C.18454E 15 C.23260E 15 0.31934E 15 0.43710E 15 0.67436E 15
C.12176E 16 C.25157E 16 C.43706E 16 0.74887E 16 0.10669E 17 0.12462E 17
```

```
                                                0.13776E 17 0.13451E 17 0.13200E 17 0.13232E 17
C.13341E 17 0.13563E 17 0.13776E 17 0.13451E 17 0.13200E 17 0.13232E 17
C.15354E 17 C.3C990E 17 C.79409E 17 0.13914E 18 0.20821E 18 0.22252E 18
0.21260E 18 C.18628E 18 C.17576E 18 0.16745E 18 0.15873E 18 0.15C83E 18
C.14271E 18 0.13582E 18 0.12897E 18 0.12270E 18 0.11646E 18 0.11C38E 18
C.104C9E 18 C.98CC1E 17 C.88900E 17 0.80347E 17 0.67273E 17
   5  E-
C.18388E 14 C.18375E 14 C.18357E 14 0.1834CE 14 0.18313E 14 0.18285E 14
0.18239E 14 C.18184E 14 C.35886E 14 0.35669E 14 0.66881E 14 0.66526E 14
C.66C64E 14 C.83745E 14 0.62884E 14 0.10941E 15 0.12660E 15 0.28873E 09
C.77908E 09 0.13193E 10 C.79507E 10 0.28566E 11 0.85367E 11 0.33859E 12
0.16139E 13 C.66465E 13 C.27078E 14 0.92979E 14 0.25150E 15 0.48672E 15
C.92474E 15 0.13854E 16 C.18430E 16 C.32094E 16 0.54234E 16 0.81486E 16
C.15788E 17 0.20589E 17 0.22795E 17 0.25136E 17 0.22743E 17 0.21383E 17
0.26205E 17 C.36113E 17 0.39921E 17 0.43CC7E 17 0.46299E 17 0.49345E 17
C.52511E 17 C.55222E 17 0.57935E 17 0.6C439E 17 0.62939E 17 0.65385E 17
0.67911E 17 0.7C356E 17 C.74039E 17 C.77471E 17 0.82648E 17
   6  C
C.39848E 16 0.39819E 16 0.39781E 16 0.39743E 16 0.39685E 16 0.39624E 16
C.39525E 16 0.39405E 16 C.52419E 16 0.52102E 16 0.67775E 16 0.67415E 16
C.66947E 16 0.96305E 16 C.95315E 16 C.14023E 17 0.18138E 17 0.24317E 17
0.34939E 17 0.53987E 17 C.71542E 17 0.99984E 17 0.12993E 18 0.16762E 18
C.20472E 18 C.22849E 18 0.23426E 18 C.23165E 18 0.22462E 18 0.21871E 18
C.21308E 18 C.20897E 18 C.20276E 18 0.19265E 18 0.17983E 18 0.16774E 18
C.1427CE 18 0.12249E 18 C.87023E 17 C.41296E 17 0.32173E 16 0.14377E 16
C.406CCE 15 C.48145E 13 0.44566E 13 C.41940E 13 C.39242E 13 0.36924E 13
C.34586E 13 C.32551E 13 0.3C586E 13 0.28857E 13 0.27175E 13 0.25576E 13
C.23949E 13 0.22412E 13 0.20166E 13 C.18130E 13 0.15051E 13
   7  H2
C.22027E 18 C.22C11E 18 0.21990E 18 0.21969E 18 0.21937E 18 0.21903E 18
C.21849E 18 0.21782E 18 C.19708E 18 C.19589E 18 0.17660E 18 0.17566E 18
0.17444E 18 0.14892E 18 0.14739E 18 C.12075E 18 0.10327E 18 0.846C8E 17
C.64189E 17 C.43537E 17 0.32396E 17 0.21270E 17 0.14063E 17 0.81731E 16
C.41982E 16 C.19335E 16 0.10602E 16 0.52539E 15 0.27092E 15 0.16261E 15
C.94527E 14 C.64496E 14 C.41732E 14 0.24563E 14 0.14808E 14 0.96325E 13
0.41256E 13 0.22296E 13 C.12031E 13 C.53253E 12 0.11792E 12 0.25514E 11
C.22237E 10 0.35648E 06 C.12882E 06 C.13437E 06 0.178C6E 06 0.18082E 06
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0.85182E 05 0.62934E 05 0.81592E 05 0.10880E 06 0.12952E 06 0.12564E 06
0.11265E 06 0.10194E 06 0.74988E 05 0.25765E 05 0.57738E 05
   8  C2
0.48657E 16 0.48622E 16 0.48575E 16 0.48528E 16 0.48458E 16 0.48383E 16
0.48263E 16 0.48115E 16 0.61466E 16 0.61094E 16 0.76320E 16 0.75914E 16
0.75387E 16 0.10244E 17 0.10139E 17 0.13980E 17 0.17215E 17 0.21715E 17
0.28553E 17 0.38494E 17 0.45367E 17 0.52320E 17 0.54444E 17 0.49695E 17
0.36068E 17 0.19615E 17 0.10700E 17 0.48996E 16 0.22672E 16 0.12589E 16
0.68971E 15 0.45708E 15 0.27839E 15 0.14949E 15 0.78388E 14 0.45361E 14
0.16154E 14 0.84614E 13 0.36113E 13 0.66122E 12 0.35403E 10 0.68295E 09
0.43418E 08 0.45140E 04 0.26492E 04 0.28436E 04 0.22866E 04 0.19567E 04
0.15728E 04 0.12727E 04 0.95441E 03 0.66745E 03 0.38327E 03 0.15054E 03
0.15941E 02 0.14218E 02 0.34669E 03 0.19817E 03 0.15653E 03
   9  H2
0.22027E 18 0.22011E 18 0.21990E 18 0.21969E 18 0.21937E 18 0.21903E 18
0.21849E 18 0.21782E 18 0.19708E 18 0.19589E 18 0.17660E 18 0.17566E 18
0.17444E 18 0.14892E 18 0.14739E 18 0.12075E 18 0.10327E 18 0.84608E 17
0.64189E 17 0.43537E 17 0.32396E 17 0.21270E 17 0.14063E 17 0.81731E 16
0.41982E 16 0.19335E 16 0.10602E 16 0.52539E 15 0.27092E 15 0.16261E 15
0.94527E 14 0.64496E 14 0.41732E 14 0.24663E 14 0.14808E 14 0.96325E 13
0.41256E 13 0.22296E 13 0.12031E 13 0.53253E 12 0.11792E 12 0.25514E 11
0.22237E 10 0.35648E 06 0.12882E 06 0.13437E 06 0.17806E 06 0.18082E 06
0.85182E 05 0.62934E 05 0.81592E 05 0.10880E 06 0.12952E 06 0.12564E 06
0.11265E 06 0.10194E 06 0.74988E 05 0.25765E 05 0.57738E 05
  10  CO
0.14358E 18 0.14348E 18 0.14334E 18 0.14320E 18 0.14300E 18 0.14278E 18
0.14242E 18 0.14198E 18 0.13783E 18 0.13700E 18 0.13268E 18 0.13198E 18
0.13106E 18 0.12550E 18 0.12421E 18 0.11775E 18 0.11256E 18 0.10664E 18
0.99199E 17 0.90050E 17 0.83917E 17 0.76254E 17 0.69874E 17 0.63102E 17
0.56758E 17 0.51319E 17 0.47748E 17 0.43516E 17 0.37995E 17 0.31211E 17
0.21256E 17 0.14145E 17 0.85819E 16 0.34716E 16 0.12665E 16 0.53723E 15
0.11570E 15 0.56477E 14 0.35756E 14 0.13558E 14 0.10293E 13 0.46588E 12
0.83171E 11 0.50265E 09 0.32191E 09 0.23276E 09 0.15911E 09 0.18469E 09
0.14291E 09 0.11261E 09 0.83698E 08 0.60787E 08 0.39748E 08 0.23611E 08
0.13233E 08 0.90124E 07 0.94772E 07 0.17649E 08 0.39265E 07
  11  C3
```

```
0.14157E 17 0.14147E 17 0.14133E 17 0.14120E 17 0.14099E 17 0.14078E 17
0.14043E 17 0.14000E 17 0.15986E 17 0.15889E 17 0.17818E 17 0.17723E 17
0.17600E 17 0.20589E 17 0.20378E 17 0.23813E 17 0.26033E 17 0.28472E 17
0.30915E 17 0.31899E 17 0.30502E 17 0.25697E 17 0.19135E 17 0.10745E 17
0.39127E 16 0.85271E 15 0.21155E 15 0.37360E 14 0.69427E 13 0.19342E 13
0.52111E 12 0.21309E 12 0.78091E 11 0.20830E 11 0.53857E 10 0.17405E 10
0.21562E 09 0.62365E 08 0.15002E 08 0.10280E 07 0.34445E 03 0.30188E 02
0.41605E 00 0.63596E-04 0.44134E-04 0.45092E-04 0.46698E-04 0.50081E-04
0.58130E-04 0.58953E-04 0.68288E-04 0.78998E-04 0.91157E-04 0.10481E-03
0.12122E-03 0.13981E-03 0.17360E-03 0.24774E-04 0.93718E-04
  12  C2H
0.10821E 18 0.10813E 18 0.10803E 18 0.10792E 18 0.10777E 18 0.10760E 18
0.10733E 18 0.10701E 18 0.10918E 18 0.10852E 18 0.10922E 18 0.10864E 18
0.10788E 18 0.10798E 18 0.10687E 18 0.10464E 18 0.10094E 18 0.95156E 17
0.85449E 17 0.69681E 17 0.57108E 17 0.40139E 17 0.26138E 17 0.13159E 17
0.46279E 16 0.10927E 16 0.30841E 15 0.65904E 14 0.14902E 14 0.47906E 13
0.14852E 13 0.66631E 12 0.26014E 12 0.80949E 11 0.24800E 11 0.92473E 10
0.14639E 10 0.46558E 09 0.13316E 09 0.14359E 08 0.33699E 05 0.29661E 04
0.47542E 02 0.13809E-03 0.21281E-03 0.23629E-03 0.26299E-03 0.29342E-03
0.34398E-03 0.36606E-03 0.47961E-03 0.58025E-03 0.58281E-04 0.49829E-04
0.39277E-04 0.27507E-04 0.30616E-04 0.12768E-03 0.12333E-04
```

```
  SAMPLE CASE FOR LRAD 3
NETA =    59
MF =     0
NS =   12
LINES =     1
 IDG =     0
 IFZ =     0

 R =0.900000E 01
 DELTA =0.507500E-01
 DTIL =0.130100E 00
 XMOL =0.100000E 01
 RDZ =0.0
```

ETA	Y	YD
0.0 *	0.345020E 04	0.0
0.400000E-01*	0.345270E 04	0.157600E-01
0.800000E-01*	0.345600E 04	0.315400E-01
0.120000E 00*	0.345930E 04	0.473600E-01
0.160000E 00*	0.346430E 04	0.632300E-01
0.200000E 00*	0.346970E 04	0.791600E-01
0.240000E 00*	0.347830E 04	0.951800E-01
0.280000E 00*	0.348900E 04	0.111300E 00
0.320000E 00*	0.350530E 04	0.127600E 00
0.360000E 00*	0.352670E 04	0.144100E 00
0.400000E 00*	0.355600E 04	0.160900E 00
0.420000E 00*	0.357500E 04	0.169500E 00
0.440000E 00*	0.360000E 04	0.178200E 00
0.460000E 00*	0.363000E 04	0.187100E 00
0.480000E 00*	0.366770E 04	0.196200E 00
0.500000E 00*	0.371470E 04	0.206600E 00
0.520000E 00*	0.377430E 04	0.215300E 00
0.540000E 00*	0.384700E 04	0.225600E 00
0.560000E 00*	0.394340E 04	0.236600E 00
0.580000E 00*	0.407310E 04	0.248500E 00
0.590000E 00*	0.416900E 04	0.255000E 00
0.598000E 00*	0.430290E 04	0.260600E 00
0.602000E 00*	0.443410E 04	0.263700E 00
0.605000E 00*	0.460860E 04	0.266200E 00
0.607500E 00*	0.483750E 04	0.268600E 00
0.610000E 00*	0.513140E 04	0.271200E 00
0.612000E 00*	0.539150E 04	0.273500E 00
0.614000E 00*	0.572830E 04	0.276000E 00
0.616000E 00*	0.608470E 04	0.278600E 00
0.618000E 00*	0.638530E 04	0.281400E 00
0.620000E 00*	0.672790E 04	0.284400E 00
0.622000E 00*	0.698230E 04	0.287600E 00
0.624000E 00*	0.729940E 04	0.290900E 00
0.626000E 00*	0.772850E 04	0.294300E 00
0.628000E 00*	0.820260E 04	0.298000E 00
0.630000E 00*	0.862950E 04	0.301800E 00
0.635000E 00*	0.949140E 04	0.312000E 00
0.640000E 00*	0.997620E 04	0.322400E 00
0.645000E 00*	0.102320E 05	0.332400E 00
0.650000E 00*	0.105730E 05	0.342000E 00
0.660000E 00*	0.107870E 05	0.359700E 00
0.670000E 00*	0.108490E 05	0.375400E 00
0.680000E 00*	0.112700E 05	0.390400E 00
0.700000E 00*	0.118850E 05	0.420900E 00
0.720000E 00*	0.120900E 05	0.452300E 00
0.740000E 00*	0.122510E 05	0.484800E 00
0.760000E 00*	0.124190E 05	0.518300E 00
0.780000E 00*	0.125710E 05	0.552700E 00
0.800000E 00*	0.127280E 05	0.588100E 00
0.820000E 00*	0.128620E 05	0.624500E 00
0.840000E 00*	0.129970E 05	0.662000E 00
0.860000E 00*	0.131220E 05	0.700500E 00
0.880000E 00*	0.132480E 05	0.739800E 00
0.900000E 00*	0.133730E 05	0.780100E 00
0.920000E 00*	0.135060E 05	0.821500E 00
0.940000E 00*	0.136380E 05	0.863900E 00
0.960000E 00*	0.138390E 05	0.907100E 00
0.980000E 00*	0.140400E 05	0.952100E 00
0.100000E 01*	0.143730E 05	0.100000E 01

FLAG ON ETA INDICATES POINT ALSO USED AS ETZ POINT

ETA	O2	N2	O	N	E	C
0.0	0.601630E 04	0.102830E 17	0.744920E 11	0.257060E 14	0.183880E 14	0.398480E 16
0.400000E-01	0.601200E 04	0.102750E 17	0.744380E 11	0.256870E 14	0.183750E 14	0.398190E 16
0.800000E-01	0.600620E 04	0.102650E 17	0.743660E 11	0.256620E 14	0.183570E 14	0.397810E 16
0.120000E 00	0.600040E 04	0.102550E 17	0.742950E 11	0.256370E 14	0.183400E 14	0.397430E 16
0.160000E 00	0.599170E 04	0.102400E 17	0.741869E 11	0.256000E 14	0.183130E 14	0.396850E 16
0.200000E 00	0.598250E 04	0.102250E 17	0.740730E 11	0.255610E 14	0.182850E 14	0.396240E 16
0.240000E 00	0.596760E 04	0.101990E 17	0.738890E 11	0.254970E 14	0.182390E 14	0.395250E 16
0.280000E 00	0.594940E 04	0.101680E 17	0.736630E 11	0.254190E 14	0.181840E 14	0.394050E 16
0.320000E 00	0.912840E 04	0.960660E 16	0.962840E 11	0.319660E 14	0.358860E 14	0.524190E 16
0.360000E 00	0.907310E 04	0.954840E 16	0.957010E 11	0.317720E 14	0.356690E 14	0.521020E 16
0.400000E 00	0.696800E 04	0.896650E 16	0.122500E 12	0.390210E 14	0.668810E 14	0.677750E 16
0.420000E 00	0.693100E 04	0.891080E 16	0.121850E 12	0.388130E 14	0.665260E 14	0.674150E 16
0.440000E 00	0.688280E 04	0.885650E 16	0.121000E 12	0.385440E 14	0.660640E 14	0.669470E 16
0.460000E 00	0.110690E 05	0.803880E 16	0.170710E 12	0.510790E 14	0.837450E 14	0.963050E 16
0.480000E 00	0.109550E 05	0.795620E 16	0.168950E 12	0.505540E 14	0.828840E 14	0.953150E 16
0.500000E 00	0.220470E 05	0.700290E 16	0.244710E 12	0.677690E 14	0.109410E 15	0.140230E 17
0.520000E 00	0.298250E 05	0.630110E 16	0.314800E 12	0.818900E 14	0.126600E 15	0.181300E 17
0.540000E 00	0.386830E 05	0.552500E 16	0.423390E 12	0.101690E 15	0.208730E 09	0.243170E 17
0.560000E 00	0.323630E 05	0.459040E 16	0.620970E 12	0.132640E 15	0.779080E 09	0.349390E 17
0.580000E 00	0.103050E 06	0.357700E 16	0.102970E 13	0.184540E 15	0.131930E 10	0.539870E 17
0.590000E 00	0.154300E 06	0.300910E 16	0.149530E 13	0.232600E 15	0.795070E 10	0.715420E 17
0.598000E 00	0.293540E 06	0.244620E 16	0.253680E 13	0.319340E 15	0.205660E 11	0.999840E 17
0.602000E 00	0.568520E 06	0.211360E 16	0.432340E 13	0.437100E 15	0.853670E 11	0.129930E 18
0.605000E 00	0.899160E 06	0.192590E 16	0.904600E 13	0.674360E 15	0.330590E 12	0.167620E 18
0.607500E 00	0.389120E 07	0.197490E 16	0.248980E 14	0.121760E 16	0.161390E 13	0.204720E 18
0.610000E 00	0.450780E 08	0.223050E 16	0.916320E 14	0.251570E 16	0.664650E 13	0.220490E 18
0.612000E 00	0.243190E 09	0.232870E 16	0.276970E 15	0.437060E 16	0.270780E 14	0.234260E 18
0.614000E 00	0.182690E 10	0.200100E 16	0.103870E 16	0.748870E 16	0.929790E 14	0.231650E 18
0.616000E 00	0.114350E 11	0.128180E 16	0.346800E 16	0.106690E 17	0.251500E 15	0.224620E 18
0.618000E 00	0.384800E 11	0.729500E 15	0.789280E 16	0.124620E 17	0.486720E 15	0.218710E 18
0.620000E 00	0.931599E 11	0.338970E 15	0.153160E 17	0.133410E 17	0.924740E 15	0.213080E 18
0.622000E 00	0.127490E 12	0.189390E 15	0.207850E 17	0.135630E 17	0.138540E 16	0.208970E 18
0.624000E 00	0.176150E 12	0.940790E 14	0.240540E 17	0.137760E 17	0.184300E 16	0.202760E 18
0.626000E 00	0.147890E 12	0.376130E 14	0.277870E 17	0.134510E 17	0.320940E 16	0.192650E 18
0.628000E 00	0.102160E 12	0.153530E 14	0.282520E 17	0.132000E 17	0.542340E 16	0.179830E 18
0.630000E 00	0.714209E 11	0.769640E 13	0.277510E 17	0.132320E 17	0.814860E 16	0.167740E 18
0.635000E 00	0.384670E 11	0.305160E 13	0.260890E 17	0.153540E 17	0.157880E 17	0.142700E 18
0.640000E 00	0.349720E 11	0.683380E 13	0.292830E 17	0.309900E 17	0.205890E 17	0.122490E 18
0.645000E 00	0.460860E 11	0.334430E 14	0.358580E 17	0.794090E 17	0.227950E 17	0.870230E 17
0.650000E 00	0.554110E 11	0.709020E 14	0.426170E 17	0.139140E 18	0.251360E 17	0.412960E 17
0.660000E 00	0.768060E 11	0.127190E 15	0.526370E 17	0.208210E 18	0.227430E 17	0.321730E 16
0.670000E 00	0.876539E 11	0.136480E 15	0.570000E 17	0.222520E 18	0.213830E 17	0.143770E 16
0.680000E 00	0.700020E 11	0.828200E 14	0.555780E 17	0.212600E 18	0.262050E 17	0.406000E 15
0.700000E 00	0.454880E 11	0.369300E 14	0.502350E 17	0.186280E 18	0.361130E 17	0.481450E 13
0.720000E 00	0.386270E 11	0.277590E 14	0.479520E 17	0.175760E 18	0.399210E 17	0.445650E 13
0.740000E 00	0.339030E 11	0.221460E 14	0.461440E 17	0.167450E 18	0.430070E 17	0.419400E 13
0.760000E 00	0.295210E 11	0.174550E 14	0.442420E 17	0.158730E 18	0.462990E 17	0.392420E 13
0.780000E 00	0.259820E 11	0.140350E 14	0.425110E 17	0.150830E 18	0.493450E 17	0.369240E 13
0.800000E 00	0.227210E 11	0.111780E 14	0.407210E 17	0.142710E 18	0.525110E 17	0.345860E 13
0.820000E 00	0.202180E 11	0.918050E 13	0.391900E 17	0.135820E 18	0.552220E 17	0.325510E 13
0.840000E 00	0.179510E 11	0.752180E 13	0.376580E 17	0.128970E 18	0.579350E 17	0.305860E 13
0.860000E 00	0.160460E 11	0.623940E 13	0.362420E 17	0.122700E 18	0.604390E 17	0.288570E 13
0.880000E 00	0.142990E 11	0.515590E 13	0.348190E 17	0.116460E 18	0.629390E 17	0.271750E 13
0.900000E 00	0.127300E 11	0.425820E 13	0.334180E 17	0.110380E 18	0.653350E 17	0.255760E 13
0.920000E 00	0.112350E 11	0.347190E 13	0.319520E 17	0.104090E 18	0.679110E 17	0.239450E 13
0.940000E 00	0.990220E 10	0.282830E 13	0.305120E 17	0.980010E 17	0.703560E 17	0.224120E 13
0.960000E 00	0.810130E 10	0.204800E 13	0.283220E 17	0.889000E 17	0.740370E 17	0.201660E 13
0.980000E 00	0.660330E 10	0.147950E 13	0.262090E 17	0.803460E 17	0.774710E 17	0.181300E 13
0.100000E 01	0.464210E 10	0.852710E 12	0.223570E 17	0.672730E 17	0.826480E 17	0.150510E 13

ETA	H	C2	H2	CO	C3	C2H
0.0	0.220270E 18	0.486570E 16	0.220270E 18	0.143580E 18	0.141570E 17	0.108210E 18
0.400000E-01	0.220110E 18	0.486220E 16	0.220110E 18	0.143400E 18	0.141470E 17	0.108130E 18
0.800000E-01	0.219900E 18	0.485750E 16	0.219900E 18	0.143340E 18	0.141330E 17	0.108030E 10
0.120000E 00	0.219690E 18	0.485280E 16	0.219690E 18	0.143200E 18	0.141200E 17	0.107920E 18
0.160000E 00	0.219370E 18	0.484580E 16	0.219370E 18	0.143000E 18	0.140990E 17	0.107770E 18
0.200000E 00	0.219030E 18	0.483830E 16	0.219030E 18	0.142780E 18	0.140780E 17	0.107600E 18
0.240000E 00	0.218490E 18	0.482630E 16	0.218490E 18	0.142420E 18	0.140430E 17	0.107330E 18
0.280000E 00	0.217820E 18	0.481150E 16	0.217820E 18	0.141980E 18	0.140000E 17	0.107010E 18
0.320000E 00	0.197080E 18	0.614660E 16	0.197080E 18	0.137830E 18	0.159860E 17	0.109180E 18
0.360000E 00	0.195890E 18	0.610940E 16	0.195890E 18	0.137000E 18	0.158890E 17	0.108520E 18
0.400000E 00	0.176600E 18	0.763200E 16	0.176600E 18	0.132680E 18	0.178180E 17	0.109220E 18
0.420000E 00	0.175660E 18	0.759140E 16	0.175660E 18	0.131980E 18	0.177230E 17	0.108640E 18
0.440000E 00	0.174440E 18	0.753870E 16	0.174440E 18	0.131060E 18	0.176000E 17	0.107880E 18
0.460000E 00	0.148920E 18	0.102440E 17	0.148920E 18	0.125500E 18	0.205890E 17	0.107980E 18
0.480000E 00	0.147390E 18	0.101390E 17	0.147390E 18	0.124210E 18	0.203780E 17	0.106870E 18
0.500000E 00	0.120750E 18	0.135800E 17	0.120750E 18	0.117750E 18	0.238130E 17	0.104640E 18
0.520000E 00	0.103270E 18	0.172150E 17	0.103270E 18	0.112560E 18	0.260330E 17	0.100940E 18
0.540000E 00	0.846080E 17	0.217150E 17	0.846080E 17	0.106640E 18	0.284720E 17	0.951560E 17
0.560000E 00	0.641890E 17	0.265530E 17	0.641890E 17	0.991990E 17	0.309150E 17	0.854490E 17
0.580000E 00	0.435370E 17	0.384940E 17	0.435370E 17	0.900499E 17	0.318990E 17	0.696810E 17
0.590000E 00	0.323960E 17	0.453670E 17	0.323960E 17	0.839170E 17	0.305020E 17	0.571080E 17
0.598000E 00	0.212700E 17	0.523200E 17	0.212700E 17	0.762539E 17	0.256970E 17	0.401390E 17
0.602000E 00	0.140630E 17	0.544440E 17	0.140630E 17	0.698740E 17	0.191350E 17	0.261380E 17
0.605000E 00	0.817310E 16	0.496950E 17	0.817310E 16	0.631020E 17	0.107450E 17	0.131590E 17
0.607500E 00	0.419820E 16	0.360680E 17	0.419820E 16	0.567580E 17	0.391270E 16	0.462790E 16
0.610000E 00	0.193350E 16	0.196150E 17	0.193350E 16	0.513190E 17	0.852710E 15	0.109270E 16
0.612000E 00	0.106020E 16	0.107000E 17	0.106020E 16	0.477480E 17	0.211550E 15	0.308410E 15
0.614000E 00	0.525390E 15	0.485560E 16	0.525390E 15	0.435160E 17	0.373600E 14	0.659040E 14
0.616000E 00	0.270920E 15	0.226720E 16	0.270920E 15	0.379950E 17	0.694270E 13	0.149020E 14
0.618000E 00	0.162610E 15	0.125890E 16	0.162610E 15	0.312110E 17	0.193420E 13	0.479060E 13
0.620000E 00	0.945270E 14	0.689710E 15	0.945270E 14	0.212560E 17	0.521110E 12	0.148520E 13
0.622000E 00	0.644960E 14	0.457080E 15	0.644960E 14	0.141450E 17	0.213090E 12	0.666310E 12
0.624000E 00	0.417320E 14	0.278390E 15	0.417320E 14	0.850190E 16	0.780910E 11	0.260140E 12
0.626000E 00	0.246630E 14	0.149490E 15	0.246630E 14	0.347160E 16	0.208300E 11	0.809490E 11
0.628000E 00	0.148080E 14	0.783880E 14	0.148080E 14	0.126650E 16	0.538570E 10	0.248000E 11
0.630000E 00	0.963250E 13	0.453610E 14	0.963250E 13	0.537230E 15	0.174050E 10	0.924730E 10
0.635000E 00	0.412560E 13	0.161540E 14	0.412560E 13	0.115700E 15	0.215620E 09	0.146390E 10
0.640000E 00	0.222960E 13	0.646140E 13	0.222960E 13	0.564770E 14	0.623650E 08	0.465580E 09
0.645000E 00	0.120310E 13	0.361130E 13	0.120310E 13	0.357560E 14	0.150020E 08	0.133160E 09
0.650000E 00	0.532530E 12	0.661220E 12	0.532530E 12	0.135580E 14	0.102800E 07	0.143590E 08
0.660000E 00	0.117920E 12	0.354030E 10	0.117920E 12	0.102930E 13	0.344450E 03	0.336990E 05
0.670000E 00	0.255140E 11	0.682950E 09	0.255140E 11	0.465880E 12	0.301880E 02	0.296610E 04
0.680000E 00	0.222370E 10	0.434180E 08	0.222370E 10	0.831710E 11	0.416050E 00	0.475420E 02
0.700000E 00	0.356480E 06	0.451400E 04	0.356480E 06	0.502650E 09	0.635960E-04	0.138090E-03
0.720000E 00	0.128820E 06	0.264920E 04	0.128820E 06	0.321910E 09	0.441340E-04	0.212810E-03
0.740000E 00	0.134370E 06	0.284360E 04	0.134370E 06	0.232760E 09	0.450920E-04	0.236290E-03
0.760000E 00	0.178060E 06	0.228660E 04	0.178060E 06	0.159110E 09	0.465980E-04	0.262990E-03
0.780000E 00	0.180820E 06	0.195670E 04	0.180820E 06	0.184690E 09	0.500810E-04	0.293420E-03
0.800000E 00	0.851620E 05	0.157280E 04	0.851820E 05	0.142910E 09	0.581300E-04	0.343980E-03
0.820000E 00	0.629340E 05	0.127270E 04	0.629340E 05	0.112610E 09	0.589530E-04	0.366060E-03
0.840000E 00	0.815920E 05	0.954410E 03	0.815920E 05	0.836980E 08	0.682880E-04	0.479610E-03
0.860000E 00	0.108800E 06	0.667450E 03	0.108800E 06	0.607870E 08	0.789980E-04	0.580250E-03
0.880000E 00	0.129520E 06	0.383270E 03	0.129520E 06	0.397480E 08	0.911570E-04	0.582810E-04
0.900000E 00	0.125640E 06	0.150540E 03	0.125640E 06	0.236110E 08	0.104810E-03	0.498290E-04
0.920000E 00	0.112650E 06	0.159410E 02	0.112650E 06	0.132330E 08	0.121220E-03	0.392770E-04
0.940000E 00	0.101940E 06	0.142180E 02	0.101940E 06	0.901240E 07	0.139810E-03	0.275070E-04
0.960000E 00	0.749880E 05	0.346690E 03	0.749880E 05	0.947720E 07	0.173600E-03	0.306160E-04
0.980000E 00	0.257650E 05	0.198170E 03	0.257650E 05	0.176490E 08	0.247740E-04	0.127680E-03
0.100000E 01	0.577380E 05	0.156530E 03	0.577380E 05	0.392650E 07	0.937180E-04	0.123330E-03

DELTA= 1.3921764E 01 CM

NUMBER DENSITIES (PARTICLES/CM3)

ETA	O2	N2	O	N	E-	C
0.0	1.0283E 16	6.0163E 03	2.5706E 13	7.4492E 10	1.8388E 13	3.9848E 15
4.0000E-02	1.0275E 16	6.0120E 03	2.5687E 13	7.4438E 10	1.8375E 13	3.9819E 15
8.0000E-02	1.0265E 16	6.0062E 03	2.5662E 13	7.4366E 10	1.8357E 13	3.9781E 15
1.2000E-01	1.0255E 16	6.0004E 03	2.5637E 13	7.4295E 10	1.8340E 13	3.9743E 15
1.6000E-01	1.0240E 16	5.9917E 03	2.5600E 13	7.4187E 10	1.8313E 13	3.9685E 15
2.0000E-01	1.0225E 16	5.9825E 03	2.5561E 13	7.4073E 10	1.8285E 13	3.9624E 15
2.4000E-01	1.0199E 16	5.9676E 03	2.5497E 13	7.3889E 10	1.8239E 13	3.9525E 15
2.8000E-01	1.0168E 16	5.9494E 03	2.5419E 13	7.3663E 10	1.8184E 13	3.9405E 15
3.2000E-01	9.6066E 15	9.1284E 03	3.1966E 13	9.6284E 10	3.5886E 13	5.2419E 15
3.6000E-01	9.5484E 15	9.0731E 03	3.1772E 13	9.5701E 10	3.5669E 13	5.2102E 15
4.0000E-01	8.9665E 15	6.9680E 03	3.9021E 13	1.2250E 11	6.6881E 13	6.7775E 15
4.2000E-01	8.9188E 15	6.9310E 03	3.8813E 13	1.2185E 11	6.6526E 13	6.7415E 15
4.4000E-01	8.8569E 15	6.8828E 03	3.8544E 13	1.2100E 11	6.6064E 13	6.6947E 15
4.6000E-01	8.0308E 15	1.1069E 04	5.1079E 13	1.7071E 11	8.3745E 13	9.6305E 15
4.8000E-01	7.9562E 15	1.0955E 04	5.0554E 13	1.6895E 11	8.2084E 13	9.5315E 15
5.0000E-01	7.0029E 15	2.2047E 04	6.7769E 13	2.4471E 11	1.0941E 14	1.4023E 16
5.2000E-01	6.3011E 15	2.9825E 04	8.1890E 13	3.1480E 11	1.2660E 14	1.8138E 16
5.4000E-01	5.5250E 15	3.8683E 04	1.0169E 14	4.2339E 11	2.8873E 08	2.4317E 16
5.6000E-01	4.5904E 15	3.2363E 04	1.3264E 14	6.2097E 11	7.7908E 08	3.4939E 16
5.8000E-01	3.5770E 15	1.0305E 05	1.8454E 14	1.0297E 12	1.3193E 09	5.3987E 16
5.9000E-01	3.0091E 15	1.5430E 05	2.3260E 14	1.4953E 12	7.9507E 09	7.1542E 16
5.9800E-01	2.4462E 15	2.9354E 05	3.1934E 14	2.5388E 12	2.8566E 10	9.9984E 16
6.0200E-01	2.1136E 15	5.6852E 05	4.3710E 14	4.3234E 12	8.5367E 10	1.2993E 17
6.0500E-01	1.9259E 15	8.9916E 05	6.7436E 14	5.0460E 12	3.3859E 11	1.6762E 17
6.0750E-01	1.9749E 15	3.8912E 06	1.2176E 15	2.4858E 13	1.6139E 12	2.0472E 17
6.1000E-01	2.2305E 15	4.5078E 07	2.5157E 15	9.1632E 13	6.6465E 12	2.2849E 17
6.1200E-01	2.3287E 15	2.4319E 08	4.3706E 15	2.7897E 14	2.7078E 13	2.3426E 17
6.1400E-01	2.0010E 15	1.8269E 09	7.4887E 15	1.0387E 15	9.2979E 13	2.3165E 17
6.1600E-01	1.2818E 15	1.1435E 10	1.0669E 16	3.4680E 15	2.5150E 14	2.2462E 17
6.1800E-01	7.2950E 14	3.8480E 10	1.2462E 16	7.0928E 15	4.8672E 14	2.1871E 17
6.2000E-01	3.3897E 14	9.3160E 10	1.3341E 16	1.5316E 16	9.2474E 14	2.1308E 17
6.2200E-01	1.8939E 14	1.2749E 11	1.3563E 16	2.0785E 16	1.3854E 15	2.0897E 17
6.2400E-01	9.4079E 13	1.7615E 11	1.3776E 16	2.4654E 16	1.8430E 15	2.0276E 17
6.2600E-01	3.7613E 13	1.4789E 11	1.3451E 16	2.7787E 16	3.2094E 15	1.9265E 17
6.2800E-01	1.5353E 13	1.0216E 11	1.3200E 16	2.1252E 16	5.4234E 15	1.7983E 17
6.3000E-01	7.6964E 12	7.1421E 10	1.3232E 16	2.7751E 16	8.1486E 15	1.6774E 17
6.3500E-01	3.0516E 12	3.8467E 10	1.5354E 16	2.6889E 16	1.5788E 16	1.4270E 17
6.4000E-01	6.8330E 12	3.4972E 10	3.0990E 16	2.9283E 16	2.0589E 16	1.2249E 17
6.4500E-01	3.3443E 13	4.6086E 10	7.9409E 16	3.5858E 16	2.2795E 16	8.7023E 16
6.5000E-01	7.0902E 13	5.5411E 10	1.3914E 17	4.2617E 16	2.5136E 16	4.1296E 16
6.6000E-01	1.2719E 14	7.6806E 10	2.0821E 17	5.2637E 16	2.2743E 16	3.2173E 15
6.7000E-01	1.3648E 14	8.7654E 10	2.2252E 17	5.7000E 16	2.1383E 16	1.4377E 15
6.8000E-01	8.2820E 13	7.0002E 10	2.1260E 17	5.5578E 16	2.6205E 16	4.0600E 14
7.0000E-01	3.6930E 13	4.5488E 10	1.8628E 17	5.0235E 16	3.6113E 16	4.0145E 12
7.2000E-01	2.7759E 13	3.8627E 10	1.7576E 17	4.7952E 16	3.9921E 16	4.4566E 12
7.4000E-01	2.2146E 13	3.3903E 10	1.6745E 17	4.6144E 16	4.3007E 16	4.1940E 12
7.6000E-01	1.7455E 13	2.9521E 10	1.5873E 17	4.4242E 16	4.6299E 16	3.9242E 12
7.8000E-01	1.4035E 13	2.5982E 10	1.5083E 17	4.2511E 16	4.9345E 16	3.6924E 12
8.0000E-01	1.1178E 13	2.2721E 10	1.4271E 17	4.0721E 16	5.2511E 16	3.4586E 12
8.2000E-01	9.1805E 12	2.0218E 10	1.3582E 17	3.9190E 16	5.5222E 16	3.2551E 12
8.4000E-01	7.5218E 12	1.7951E 10	1.2897E 17	3.7658E 16	5.7935E 16	3.0586E 12
8.6000E-01	6.2394E 12	1.6046E 10	1.2270E 17	3.6242E 16	6.0439E 16	2.8857E 12
8.8000E-01	5.1559E 12	1.4299E 10	1.1646E 17	3.4819E 16	6.2939E 16	2.7175E 12
9.0000E-01	4.2582E 12	1.2730E 10	1.1030E 17	3.3418E 16	6.5385E 16	2.5576E 12
9.2000E-01	3.4719E 12	1.1235E 10	1.0409E 17	3.1952E 16	6.7911E 16	2.3949E 12
9.4000E-01	2.8283E 12	9.9022E 09	9.8001E 16	3.0512E 16	7.0356E 16	2.2412E 12
9.6000E-01	2.0480E 12	8.1013E 09	8.8900E 16	2.8322E 16	7.4039E 16	2.0166E 12
9.8000E-01	1.4795E 12	5.6033E 09	8.0347E 16	2.6209E 16	7.7471E 16	1.8130E 12
1.0000E 00	8.5271E 11	4.6421E 09	6.7273E 16	2.2857E 16	8.2648E 16	1.5051E 12

NUMBER DENSITIES (PARTICLES/CM3)

ETA	H	C2	H2	CO	C3	C2H
0.0	2.2027E 17	4.8657E 15	2.2027E 17	1.4358E 17	1.4157E 16	1.0821E 17
4.0000E-02	2.2011E 17	4.8622E 15	2.2011E 17	1.4348E 17	1.4147E 16	1.0813E 17
8.0000E-02	2.1990E 17	4.8573E 15	2.1990E 17	1.4334E 17	1.4133E 16	1.0803E 17
1.2000E-01	2.1969E 17	4.8528E 15	2.1969E 17	1.4320E 17	1.4120E 16	1.0793E 17
1.6000E-01	2.1937E 17	4.8459E 15	2.1937E 17	1.4300E 17	1.4090E 16	1.0777E 17
2.0000E-01	2.1903E 17	4.8383E 15	2.1903E 17	1.4278E 17	1.4078E 16	1.0760E 17
2.4000E-01	2.1849E 17	4.8263E 15	2.1849E 17	1.4242E 17	1.4043E 16	1.0733E 17
2.8000E-01	2.1782E 17	4.8115E 15	2.1782E 17	1.4198E 17	1.4000E 16	1.0701E 17
3.2000E-01	1.9708E 17	6.1466E 15	1.9708E 17	1.3783E 17	1.5986E 16	1.0918E 17
3.6000E-01	1.9589E 17	6.1094E 15	1.9589E 17	1.3700E 17	1.5889E 16	1.0852E 17
4.0000E-01	1.7660E 17	7.6320E 15	1.7660E 17	1.3268E 17	1.7818E 16	1.0922E 17
4.2000E-01	1.7566E 17	7.5914E 15	1.7566E 17	1.3158E 17	1.7723E 16	1.0864E 17
4.4000E-01	1.7444E 17	7.5387E 15	1.7444E 17	1.3106E 17	1.7600E 16	1.0788E 17
4.6000E-01	1.4892E 17	1.0244E 16	1.4892E 17	1.2550E 17	2.0589E 16	1.0798E 17
4.8000E-01	1.4739E 17	1.0139E 16	1.4739E 17	1.2421E 17	2.0378E 16	1.0687E 17
5.0000E-01	1.2075E 17	1.3980E 16	1.2075E 17	1.1775E 17	2.3813E 16	1.0464E 17
5.2000E-01	1.0327E 17	1.7215E 16	1.0327E 17	1.1256E 17	2.6033E 16	1.0094E 17
5.4000E-01	8.4608E 16	2.1715E 16	8.4608E 16	1.0664E 17	2.8472E 16	9.5156E 16
5.6000E-01	6.4189E 16	2.8553E 16	6.4189E 16	9.9199E 16	3.0915E 16	8.5449E 16
5.8000E-01	4.3537E 16	3.8494E 16	4.3537E 16	9.0050E 16	3.1899E 16	6.9681E 16
5.9000E-01	3.2396E 16	4.5367E 16	3.2396E 16	8.1917E 16	3.0502E 16	5.7108E 16
5.9800E-01	2.1270E 16	5.2320E 16	2.1270E 16	7.6254E 16	2.5697E 16	4.0139E 16
6.0200E-01	1.4063E 16	5.4444E 16	1.4063E 16	6.7074E 16	1.9135E 16	2.6138E 16
6.0500E-01	8.1731E 15	4.9695E 16	8.1731E 15	6.3102E 16	1.0745E 16	1.3159E 16
6.0750E-01	4.1982E 15	3.6068E 16	4.1982E 15	5.6758E 16	3.9127E 15	4.6279E 15
6.1000E-01	1.9335E 15	1.9615E 16	1.9335E 15	5.1319E 16	8.5271E 14	1.0927E 15
6.1200E-01	1.0602E 15	1.0700E 16	1.0602E 15	4.7748E 16	2.1155E 14	3.0841E 14
6.1400E-01	5.2539E 14	4.8996E 15	5.2539E 14	4.3516E 16	3.7360E 13	6.5904E 13
6.1600E-01	2.7092E 14	2.2672E 15	2.7092E 14	3.7995E 16	6.9427E 12	1.4902E 13
6.1800E-01	1.6261E 14	1.2589E 15	1.6261E 14	3.1211E 16	1.9342E 12	4.7906E 12
6.2000E-01	9.4527E 13	6.8971E 14	9.4527E 13	2.1256E 16	5.2111E 11	1.4852E 12
6.2200E-01	6.4496E 13	4.5708E 14	6.4496E 13	1.4145E 16	2.1309E 11	6.6631E 11
6.2400E-01	4.1732E 13	2.7839E 14	4.1732E 13	8.5819E 15	7.8091E 10	2.6014E 11
6.2600E-01	2.4663E 13	1.4949E 14	2.4663E 13	3.4716E 15	2.0830E 10	8.0949E 10
6.2800E-01	1.4808E 13	7.6308E 13	1.4808E 13	1.2665E 15	5.3857E 09	2.4800E 10
6.3000E-01	9.6325E 12	4.5361E 13	9.6325E 12	5.3723E 14	1.7405E 09	9.2473E 09
6.3500E-01	4.1256E 12	1.6154E 13	4.1256E 12	1.1570E 14	2.1562E 08	1.4639E 09
6.4000E-01	2.2296E 12	8.4614E 12	2.2296E 12	5.6477E 13	6.2365E 07	4.6558E 08
6.4500E-01	1.2031E 12	3.6113E 12	1.2031E 12	3.5756E 13	1.5002E 07	1.3316E 08
6.5000E-01	5.3253E 11	6.6122E 11	5.3253E 11	1.3558E 13	1.0280E 06	1.4359E 07
6.6000E-01	1.1792E 11	3.5403E 09	1.1792E 11	1.0293E 12	3.4445E 02	3.3699E 04
6.7000E-01	2.5514E 10	6.8295E 08	2.5514E 10	4.6588E 11	3.0188E 01	2.9661E 03
6.8000E-01	2.2237E 09	4.3418E 07	2.2237E 09	8.3171E 10	4.1605E-01	4.7542E 01
7.0000E-01	3.5648E 05	4.5140E 03	3.5648E 05	5.0265E 08	6.3596E-05	1.3809E-04
7.2000E-01	1.2882E 05	2.6492E 03	1.2882E 05	3.2191E 08	4.4134E-05	2.1281E-04
7.4000E-01	1.3437E 05	2.8436E 03	1.3437E 05	2.3276E 08	4.5092E-05	2.3629E-04
7.6000E-01	1.7806E 05	2.2066E 03	1.7806E 05	1.5911E 08	4.6698E-05	2.6299E-04
7.8000E-01	1.8082E 05	1.9567E 03	1.8082E 05	1.8469E 08	5.0081E-05	2.9342E-04
8.0000E-01	8.5182E 04	1.5728E 03	8.5182E 04	1.4291E 08	5.8130E-05	3.4398E-04
8.2000E-01	6.2934E 04	1.2727E 03	6.2934E 04	1.1261E 08	5.8953E-05	3.6606E-04
8.4000E-01	8.1592E 04	9.5441E 02	8.1592E 04	8.3698E 07	6.8288E-05	4.7961E-04
8.6000E-01	1.0880E 05	6.6745E 02	1.0880E 05	6.0787E 07	7.0999E-05	5.8025E-04
8.8000E-01	1.2952E 05	3.8327E 02	1.2952E 05	2.9748E 07	9.1157E-05	5.8281E-05
9.0000E-01	1.2564E 05	1.5054E 02	1.2564E 05	2.2611E 07	1.0401E-04	4.9829E-05
9.2000E-01	1.1265E 05	1.5941E 01	1.1265E 05	1.3233E 07	1.2122E-04	3.9277E-05
9.4000E-01	1.0194E 05	1.4218E 01	1.0194E 05	9.0124E 06	1.3901E-04	2.7507E-05
9.6000E-01	7.4988E 04	3.4669E 02	7.4988E 04	9.4772E 06	1.7350E-04	3.0616E-05
9.8000E-01	2.5765E 04	1.9017E 02	2.5765E 04	1.7649E 07	2.4774E-05	1.2768E-04
1.0000E 00	5.7738E 04	1.5653E 02	5.7738E 04	3.9265E 06	3.3710E-05	1.2333E-05

CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX

I	HNU	ETA = 0.0 QMINUS	ETA = 0.0 QPLUS	ETA = 0.500 QMINUS	ETA = 0.500 QPLUS	ETA = 1.000 QMINUS	ETA = 1.000 QPLUS
1	5.000	0.0	9.411E 02	0.0	9.411E 02	9.419E 02	0.0
2	6.000	0.0	1.747E 01	2.209E-02	2.933E 01	4.761E 01	0.0
3	7.000	0.0	1.941E 01	7.514E-04	2.541E 01	2.926E 01	0.0
4	8.000	0.0	2.241E-01	2.669E-04	8.874E 00	2.505E 01	0.0
5	9.000	-0.0	5.363E-06	2.764E-05	1.685E-01	2.203E 01	0.0
6	10.000	0.0	7.684E-02	9.062E-07	4.010E 00	1.057E 01	0.0
7	10.800	0.0	1.596E 01	1.809E-10	1.604E 01	2.180E 01	0.0
8	11.100	0.0	1.157E 02	1.125E-11	1.163E 02	2.548E 02	0.0
9	12.000	0.0	2.060E 00	5.008E-10	3.046E 00	3.978E 02	0.0
10	13.400	0.0	2.596E-11	3.256E-10	1.048E-01	9.528E 02	0.0
11	14.300	0.0	3.082E-13	5.429E-12	8.177E-03	3.411E 02	0.0
12	20.000	0.0	8.850E-02	4.022E-14	1.311E-01	5.354E 02	0.0
TOTAL FLUX		0.0	1.112E 03	2.314E-02	1.145E 03	3.581E 03	0.0

LINE CONTRIBUTION TO THE SPECTRAL FLUX

I	HNU	ETA = 0.0 QMINUS	ETA = 0.0 QPLUS	ETA = 0.500 QMINUS	ETA = 0.500 QPLUS	ETA = 1.000 QMINUS	ETA = 1.000 QPLUS
1	1.300	0.0	4.879E 02	-1.474E-11	4.879E 02	5.330E 02	0.0
2	2.700	0.0	1.799E 02	-2.947E-12	1.799E 02	1.804E 02	0.0
3	5.750	0.0	3.715E 00	2.176E-06	6.255E 00	1.946E 01	0.0
4	7.570	0.0	2.603E 00	7.326E-07	1.034E 02	5.331E 02	0.0
5	9.100	0.0	1.660E 00	8.753E-09	8.689E 01	4.595E 02	0.0
6	10.400	0.0	2.351E 02	1.077E-09	2.404E 02	1.234E 03	0.0
7	11.400	0.0	-1.044E 00	5.161E-11	-1.543E 00	7.343E 02	0.0
8	12.700	0.0	-6.951E-16	1.669E-13	-2.468E-02	1.814E 02	0.0
9	13.900	0.0	-9.990E-20	1.444E-16	-3.275E-03	8.472E 01	0.0
TOTAL FLUX		0.0	9.099E 02	2.919E-06	1.103E 03	3.960E 03	0.0

TOTAL RADIATIVE FLUX - WATTS/CM2

0.202202E 04 0.224775E 04 0.754125E 04

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C
C
C  **  THIS IS A DRIVER PROGRAM FOR SUBROUTINE TRANS WHICH CALCULATES **
C       THE RADIATIVE FLUX DIVERGENCE THROUGH A ONE-DIMENSIONAL SLAB
C       FOR A GIVEN TEMPERATURE AND SPECIES DISTRIBUTION    C ENGEL 7/71
      COMMON /SFLUX/ QRI(3)
      COMMON /TRN/ YD(60),NUT(60), FMC(12,60), FPC(12,60),
     1           FM(9,60), FP(9,60), LINES
      COMMON /MOLFRA/    X1(60),X2(60),    X3(60),    X4(60),
     1                             X7(60),  X8(60),  X9(60),  X10(60),
     2                  X11(60),   X12(60), X13 (60), X14(60)
      COMMON /TEST/ETZ(60),IEZ
      COMMON /XY/  ETA(60)
      COMMON /PROP/ P(60),  RHO(60),                T(60)
      COMMON /FRSTRM/     U INF,     RINF,      UINF2,      R,  RE,  LXI,
     1                  ITM,       ITG,       NETA
      COMMON /DEL/  DELTA,  DTIL
      COMMON /NCN/ RDZ,  MUDZ,  RMDZ
      COMMON /MAIN1/ IDG
      COMMON /RFLUX/ AMW(60),  IRAD,  ITYPE,  E(60)
      COMMON /NUMDEN/ SNDC2(60), SNDN2(60), SNDO(60), SNDN(60),
     1                                   SNDE(60), SNDC(60),
     2                 SNDH(60), SNDC2(60), SNDH2(60), SNDCO(60),
     3                 SNDC3(60),SNDC2H(60)
      COMMON /SPEC/ MF, XMOL
C
      DATA BLNK /4H    /
      DATA ASK /4H*   /
      DIMENSION DENS(60,12), TIT(20),FRAC (60,12)
      EQUIVALENCE (SNDC2(1),DENS(1,1))
      EQUIVALENCE (X1(1),FRAC(1,1))
 1    CONTINUE
C
C  **  ZERO ALL NUMBER DENSITIES AND MOLE FRACTIONS  **
C
      DO 10 I=1,60
```

```
      DO 1C J=1,12
      FRAC(I,J)=C.0
   10 DENS(I,J)=0.C
C CARD  1 -------------------------------------------------------------
      READ (5,1CC) (TIT(I),I=1,20)
      WRITE (6,114) (TIT(I),I=1,20)
C
C  **  READ OPTIONS  **
C CARD  2 -------------------------------------------------------------
      READ (5,1C1) NETA,MF,NS,LINES,IDG,IEZ
C
C  **  NETA = NUMBER OF ETA POINTS
C      MF   = 1  IF SPECIE  MOLE FRACTIONS ARE INPUT AND NUMBER DENSITY
C                TO BE COMPUTED
C             0  IF SPECIE NUMBER DENSITIES ARE INPUT
C      NS   = NUMBER OF SPECIES TO BE INPUT
C      LINES= 1  IF LINE CALCULATION IS TO BE DONE
C             0  IF ONLY CONTINUUM CALCULATION IS TO BE DONE
C      IDG  = 0  ONLY FINAL PRINT IS GIVEN
C             1  PRINT IS GIVEN FOR EACH ETA
C            99  COMPLETE PRINT
C      IEZ  = 0  IF ETA ARRAY WILL ALSO BE USED FOR ETZ.
C             OTHERWISE IEZ= NUMBER OF POINTS IN  ARRAY ETZ TO BE
C             INPUT. WILL BE LESS THAN NETA
C
      WRITE (6,1C2) NETA,MF,NS,LINES,IDG,IEZ
C
C CARD  3 -------------------------------------------------------------
      READ  (5,1C3) R,DELTA,DTIL,XMCL,RDZ
C
C  **  R      = BODY RADIUS (FT)
C      DELTA  = NONDIMENSIONAL STAND-OFF DISTANCE
C      DTIL   = TRANSFORMED STAND-OFF DISTANCE
C      XMCL   = 1.0 FOR RUN WITH MOLECULES
C               0.C FOR RUN WITHOUT MOLECULES
C
```

```
      WRITE (6,104) R, CELTA, DTIL, XMOL,RDZ                            MAIN 730
C                                                                       MAIN 740
C  **  READ TEMPERATURE, YD, AND ETA ARRAYS WHICH WILL ALWAYS BE INPUT  MAIN 750
C CARD  4 ------------------------------------------------------------- MAIN 760
      READ (5,105) (T(I),I=1,NETA)                                      MAIN 770
C CARD  5 ------------------------------------------------------------- MAIN 780
      READ (5,105) (YD(I),I=1,NETA)                                     MAIN 790
C CARD  6 ------------------------------------------------------------- MAIN 800
      READ (5,105) (ETA(I),I=1,NETA)                                    MAIN 810
C                                                                       MAIN 820
C  **  READ SPECIES DATA  **                                            MAIN 830
C                                                                       MAIN 840
      DO 30 I=1,NS                                                      MAIN 850
C CARD  7 ------------------------------------------------------------- MAIN 860
      READ (5,101) INDEX                                                MAIN 870
C                                                                       MAIN 880
C  **  INDEX IS NUMBER GIVEN SPECIE FOR USE IN STORING ARRAYS **        MAIN 890
C                         1    =    O2                                  MAIN 900
C                         2    =    N2                                  MAIN 910
C                         3    =    O                                   MAIN 920
C                         4    =    N                                   MAIN 930
C                         5    =    E-                                  MAIN 940
C                         6    =    C                                   MAIN 950
C                         7    =    H                                   MAIN 960
C                         8    =    C2                                  MAIN 970
C                         9    =    H2                                  MAIN 980
C                        10    =    CO                                  MAIN 990
C                        11    =    C3                                  MAIN1000
C                        12    =    C2H                                 MAIN1010
C                                                                       MAIN1020
      IF (MF.EQ.1) GO TO 20                                             MAIN1030
C  **  READ NUMBER DENSITIES  **                                        MAIN1040
C CARD 8A ------------------------------------------------------------- MAIN1050
      READ (5,105) (DENS(K,INDEX),K=1,NETA)                             MAIN1060
      GO TO 30                                                          MAIN1070
C                                                                       MAIN1080
```

```
C  **  READ MOLE FRACTIONS  **                                           MAIN1090
C CARD 8B -------------------------------------------------------------- MAIN1100
   20 READ (5,105) (FRAC(K,INDEX),K=1,NETA)                              MAIN1110
   30 CONTINUE                                                           MAIN1120
   35 IF (IEZ.EQ.0) GO TO 40                                             MAIN1130
C                                                                        MAIN1140
C CARD  9 -------------------------------------------------------------- MAIN1150
      READ (5,105) (ETZ(I),I=1,IEZ)                                      MAIN1160
      IEZ=IEZ-1                                                          MAIN1170
      GO TO 60                                                           MAIN1180
   40 IEZ=NETA-1                                                         MAIN1190
      DO 50 I=1,NETA                                                     MAIN1200
   50 ETZ(I)=ETA(I)                                                      MAIN1210
   60 IF (MF.NE.1) GO TO 70                                              MAIN1220
C  **  IF NEEDED , READ DENSITY AND MOLECULAR WEIGHT ARRAYS, FOR FIGURINMAIN1230
C       NUMBER DENSITY, GIVEN MOLE FRACTIONS  **                         MAIN1240
C CARD 10 -------------------------------------------------------------- MAIN1250
      READ (5,105) (RHO(I),I=1,NETA)                                     MAIN1260
C CARD 11 -------------------------------------------------------------- MAIN1270
      READ (5,105) (AMW(I),I=1,NETA)                                     MAIN1280
C                                                                        MAIN1290
C  **  WRITE INPUT ARRAYS  **                                            MAIN1300
C                                                                        MAIN1310
   70 IF (MF.EQ.1) GO TO 120                                             MAIN1320
      WRITE (6,106)                                                      MAIN1330
      N=1                                                                MAIN1340
      DO 80 I=1,NETA                                                     MAIN1350
      IF (ETA(I).EQ.ETZ(N)) GO TO 96                                     MAIN1360
      FLAG=BLNK                                                          MAIN1370
      GO TO 80                                                           MAIN1380
   96 N=N+1                                                              MAIN1390
      FLAG=ASK                                                           MAIN1400
   80 WRITE (6,107) ETA(I), FLAG, T(I), YD(I)                            MAIN1410
      WRITE (6,108)                                                      MAIN1420
      WRITE (6,109)                                                      MAIN1430
      DO 90 I=1,NETA                                                     MAIN1440
```

```
                                                                     MAIN1450
 90 WRITE (6,112) ETA(I), SNDO2(I),SNDN2(I),SNDO(I),SNDN(I),         MAIN1460
   1                        SNDE(I),SNDC(I)                          MAIN1470
    WRITE (6,110)                                                    MAIN1480
    DO 94  I=1,NETA                                                  MAIN1490
 94 WRITE (6,112) ETA(I),SNDH(I),SNDC2(I),SNDH2(I),SNDCO(I),SNDC3(I) MAIN1500
   1  ,SNDC2H(I)                                                     MAIN1510
    GO TO 170                                                        MAIN1520
120 WRITE (6,111)                                                    MAIN1530
    N=1                                                              MAIN1540
    DO 130 I=1,NETA                                                  MAIN1550
    IF (ETA(I).EQ.ETZ(N)) GO TO 160                                  MAIN1560
    FLAG=BLNK                                                        MAIN1570
    GO TO 130                                                        MAIN1580
160 N=N+1                                                            MAIN1590
    FLAG=ASK                                                         MAIN1600
130 WRITE (6,107) ETA(I),FLAG,T(I), YC(I), RHO(I), AMW(I)            MAIN1610
    WRITE (6,108)                                                    MAIN1620
    WRITE (6,109)                                                    MAIN1630
    DO 140 I=1,NETA                                                  MAIN1640
140 WRITE (6,112) ETA(I), X1(I), X2(I), X3(I), X4(I),                MAIN1650
   1                  X7(I), X8(I)                                   MAIN1660
    WRITE (6,110)                                                    MAIN1670
    DO 150 I=1,NETA                                                  MAIN1680
150 WRITE (6,112) ETA(I), X9(I), X10(I), X11(I), X12(I), X13(I),X14(I)MAIN1690
    GO TO 170                                                        MAIN1700
170 CALL TRANS(1)                                                    MAIN1710
    CALL TRANS2                                                      MAIN1720
C                                                                    MAIN1730
    WRITE (6,113) (QRI(I),I=1,3)                                     MAIN1740
C                                                                    MAIN1750
    GO TO 1                                                          MAIN1760
    STOP                                                             MAIN1770
100 FORMAT (20A4)                                                    MAIN1780
101 FORMAT (6I5)                                                     MAIN1790
102 FORMAT (7H NETA =,I5/5H MF =,I5/5H NS =,I5/8H LINES =,I5/        MAIN1800
   1 6H IDG =,I5/6H IEZ =,I5/)
```

```
103 FORMAT (5E12.0)
104 FORMAT (4H R =,E12.6/8H DELTA =,E12.6/7H DTIL =,E12.6/7H XMCL =,
   1           E12.6/,6H RDZ =,E12.6/)
105 FORMAT (6E12.0)
106 FORMAT (1H1,6X,3HETA,17X,1HT,13X,2HYD//)
107 FORMAT (1H ,E15.6,A4,3E15.6)
108 FORMAT  (' FLAG ON ETA INDICATES POINT ALSO USED AS ETZ POINT')
109 FORMAT (1H1,4X,3HETA,11X,2HC2,13X,2HN2,14X,1HO,14X,1HN,
   1                14X,1HE,14X,1HC//)
110 FORMAT (1H1,4X,3HETA,12X,1HH,13X,2HC2,13X,2HH2,13X,2HCO,13X,2HC3,
   1 13X,3HC2H//)
111 FORMAT (1H1,6X,3HETA,17X,1HT,13X,2HYD,12X,3HRHO,12X,3HAMW//)
112 FORMAT (1H ,E12.6,6E15.6)
113 FORMAT (1H1,32HTOTAL RADIATIVE FLUX - WATTS/CM2 // 3E15.6)
114 FORMAT (1H1,20A4)
    END
```

```
      SUBROUTINE TRANS (ISW)                                            TRAN  10
C                                                                       TRAN  20
C-----THIS IS A MODIFIED VERSION OF SUBROUTINE TRANS FROM K WILSON      TRAN  30
C     TRANS IS DOCUMENTED IN  LMSC-687209 APRIL 69  ----------------    TRAN  40
C                                                                       TRAN  50
      COMMON /ZPI/ ZPO(6), ZPN(6),ZPH(2),  ZPC(7)                       TRAN  60
      COMMON /FINV/ NHVL,NIHVC,FHVC(12),CJ(9),HVJ(9),ZKZ                TRAN  70
      COMMON /SFLUX/ CRI(3)                                             TRAN  80
      COMMON /TRN/ YD(60),NUT(60), FMC(12,60), FPC(12,60),              TRAN  90
     1          FM(9,60), FP(9,60), LINES                               TRAN 100
      COMMON /MCLFRA/    X1(60),X2(60),   X3(60),   X4(60),             TRAN 110
     1                          X7(60),  X8(60),  X9(60),  X10(60),     TRAN 120
     2                  X11(60),  X12(60), X13 (60), X14(60)            TRAN 130
      COMMON /XY/   ETA(60)                                             TRAN 140
      COMMON /PRCP/ P(60),     R(60),                   T(60)           TRAN 150
      COMMON /FRSTRM/    U INF,     RINF,      UINF2,     XL,  RE,  LXI, TRAN 160
     1                  ITM,      ITG,       NES                        TRAN 170
      COMMON /DEL/  W(1),      DS                                       TRAN 180
      COMMON /NCN/ RDZ,  MUDZ,  RNDZ                                    TRAN 190
      COMMON /MAIN1/ IDG                                                TRAN 200
      COMMON /RFLUX/ AMW(60),   IRAD,  ITYPE,  E(60)                    TRAN 210
      COMMON /TEST/ETZ(60),IEZ                                          TRAN 220
      COMMON /NUMDEN/ SNDO2(60), SNDN2(60), SNDO(60), SNDN(60),         TRAN 230
     1                                    SNDE(60), SNDC(60),           TRAN 240
     2                SNCH(60), SNDC2(60), SNDH2(60), SNDCO(60),        TRAN 250
     3                SNCC3(60),SNDC2H(60)                              TRAN 260
      COMMON /DBUG/ QLC(60), QCL(60), CLL(60), DCN(60), QCC(60),        TRAN 270
     1              BEEC(12,60),    FMUC(12,60),   EM(12,60),           TRAN 280
     2              EP(12,60),      TAUC(12,60),   BEEL(9,60),          TRAN 290
     3              QCCP(12),       WMM(9,60),     GMM(9,60),           TRAN 300
     4              EEM(9,60),      XLMM(9,60),    QLCP(9),             TRAN 310
     5              QCLP(9),        CLLP(9),       DELTA,     IY,  IYY,  TRAN 320
     6              WPP(9,60),      GPP(9,60),     EEP(9,60),           TRAN 330
     7              XLPP(9,60),     FG(9,4),       GP(9,4),    L,       TRAN 340
     8              WN(9,4),        FMUL(9,60),    SSM(9,4,60),         TRAN 350
     9              CGM(9,4,60),    ETAM(9,4,60),  SBM(9,4,60),         TRAN 360
```

```
     A                  TAUL(9,60)
      COMMON /SPEC/ MF, XMOL
      DIMENSION  XKT(60),          DQ(60)
C
C **   BAND AVERAGE ABSORPTION CROSS SECTION (EQ.A2)  **
C
      SIGMA(ZH,ZA,ZB,ZG)=  ((5.0E+03*T1*ZG*ZKZ)/BE) * (EXP(ZDL/T1)
     1                     *ZH*(ZA+ZB* (ZH**2)/3.0) +
     2                     T1 * (ZA+2.0*ZB*T12) -T1*EXP((ZH-ZHVP)/T1)
     3                     *(ZA+ZB*(ZHVP-ZH)**2) -T1*EXP((ZH-ZHVP)/T1)
     4                     *2.0*ZB*T1*(ZHVP-ZH+T1))
      SIGMA2(ZH,ZG,ZE,ZY)=7.26E-16*T1*ZG*EXP((-ZE+ZY+ZDL)/T1)/ZH**3
      GAMMA(ZX)=(1.0+(1.5707963*ZX)**1.25)**(-0.4)
      XLAMB(ZX)=(1.0+ZX*EXP(-ZX))/SQRT(1.0+6.283185 *ZX)
C
C **   W(GROUP)/D CORRELATION (EQ.88)  **
C
      PHI1(ZX)=(ATAN(1.570796 *ZX)/1.570796 )
C
C **   FLUX DIVERGENCE OVERLAPPING FUNCTION (EQ.92)  **
C
      PHI2(ZX)=EXP(-ZX)
C
      CALL RADIN
      ZHVP=5.0
      YI=0.0
      IF (MF.NE.0) GO TO 2000
      XNE=SNDE(NES)
      GO TO 2010
 2000 RRUCKM=3.11E+23 * R(NES) * RDZ / AMW(NES)
      XNE=X7(NES) * RRUCKM
 2010 FNE=(4.71E-6 * XNE**(2.0/7.0))/((T(NES)/11606.)**(1.0/7.0))
      ZDL=AMIN1(0.20,FNE)
C
C **   DEBUG PRINT  **
C
```

```
      IF (IDG.NE.0) CALL BUGPR (1)
      DELTA=W(1) * XL * 30.48006
      CALL BUGPR (2)
      DO 91 L=1,NES
      XKT(L)=T(L)/11606.
      T1=XKT(L)
      IF (MF.NE.0) CALL SND(L,1)
C
C **   PARTITION FUNCTIONS FOR H, C, N, O   **
C
   94 IF(T(L).GT.15000.) GO TO 6
C
C **   LOW  TEMPERATURE   **
C
      SUMH=2.0
      SUMC=9.0   +    5.0 * EXP(-1.264/T1) + EXP(-2.684/T1) +
     1                5.0 * EXP(-4.183/T1)
      SUMN=4.0 + 10.0 *EXP(-2.384/T1) + 6.0 *EXP(-3.576/T1)
      SUMO= 9.0 + 5.0 * EXP(-1.975/T1)
      GO TO 7
C
C **   HIGH TEMPERATURE   **
C
    6 SUMH=2.0
      SUMC=2.71818  +  6.40677 * T(L)/1.0E4 -0.45466 * (T(L)/1.0E4)**2
      SUMN=5.938216 - 0.225593 * T(L)/1.0E3 + 0.015408 * (T(L)/1.0E3)**2
      SUMO=11.79563 -0.317964 * T(L)/1.0E3 + 0.013765 * (T(L)/1.0E3)**2
    7 CONTINUE
      T12=T1**2
      GH = 6.4994
      DO 5 K=1,12
      GF=FHVC(K)/T1
      GHM=GH
      GH=EXP(-GF)  *GF   *  (GF**2 + 3.0 *GF  +6.0  + 6.0/GF)
C
C **   PLANK MEAN ABSCRPTION COEFFICIENT FOR BAND INTERVALS (EQ.A3)  **
```

```
C
      BEEC(K,L)=5.04E3  *  (T12**2)  *  (GHN-GH)
      EE=BEEC(K,L)
C
C **   ABSORPTICN CROSS SECTICNS  **
C      SCECIES --
C                N       N2       CO
C                O       C2
C                C       C2       C3
C                H       H2       C2H
C
      SGH=0.
      SGN=C.
      SGC=0.
      SGO=C.
      SGCO=0.
      SGC2=C.
      SGC2=0.
      SGN2=C.
      SGH2=0.
      SGC3=0.
      SGC2H = 0.0
      GO TO (581,582,583,584,585,586,587,588,589,590,591,592),K
  581 SGH=SIGMA(2.4,1.0,0.0,1.0)  *  EXP(-13.56/T1)
      SGC=SIGMA(3.78,  0.3,   0.0488,  1.33)  * EXP(-11.26/T1)
      SGN=SIGMA(4.22,  0.24,  0.0426,  4.5) * EXP(-14.54/T1)
      SGO=SIGMA(4.22,  C.24,  0.0426,   .8888889)  * EXP(-13.61/T1)
      GO TO 38
  582 ZZHV=5.5
      SGC2=8.0E-18 * EXP(-0.5/T1)  +  3.0E-18
      SGC3=4.0E-18
  593 CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)
      SGC=SIGMA2(ZZHV, 1.33,  11.26,  3.78) * ZZC + SGC
      SGN=SIGMA2 (ZZHV,4.50,  14.54,  4.22) * ZZN
  594 SGO=SIGMA2 (ZZHV, .889,  13.61,  4.22) * ZZO
  595 SGH=SIGMA2 (ZZHV, 1.00,  13.56,  2.40)
```

```
      GO TO 38                                                          TRAN1450
  583 ZZHV=6.5                                                          TRAN1460
      SGC2=1.0E-18                                                      TRAN1470
      SGCC=3.0E-18 * EXP(-0.7/T1)                                       TRAN1480
      GO TO 593                                                         TRAN1490
  584 ZZHV=7.5                                                          TRAN1500
      SGC=5.0E-17   * EXP(-4.18/T1)/SUMC                                TRAN1510
      SGCC=1.9E-17   * EXP(-0.5/T1)                                     TRAN1520
      SGC2=6.0E-19                                                      TRAN1530
      SGC2H = 1.3E-18                                                   TRAN1540
      GO TO 593                                                         TRAN1550
  585 ZZHV=8.5                                                          TRAN1560
      SGC=5.0E-17 *EXP(-4.18/T1)/SUMC   +                               TRAN1570
     1     2.2E-17* EXP(-2.68/T1)/SUMC                                  TRAN1580
      SGCO=2.5E-17                                                      TRAN1590
      SGO2=2.0E-19                                                      TRAN1600
      SGC2H = 8.5E-19                                                   TRAN1610
      GO TO 593                                                         TRAN1620
  586 ZZHV=9.5                                                          TRAN1630
      SGC=5.0E-17 * EXP(-4.18/T1)/SUMC   +                              TRAN1640
     1     2.2E-17 * EXP(-2.68/T1)/SUMC                                 TRAN1650
      SGCO=5.0E-18                                                      TRAN1660
      SGO2=1.0E-18                                                      TRAN1670
      GO TO 593                                                         TRAN1680
  587 SGN=3.2E-18 *T1 *EXP(-10.2/T1)/SUMN                               TRAN1690
      SGO2=6.0E-19                                                      TRAN1700
      ZZHV=10.4                                                         TRAN1710
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1720
  596 SGC=(8.5E-17 *EXP(-1.26/T1)   +   2.2E-17 * EXP(-2.75/T1)         TRAN1730
     1     +  5.0E-17 * EXP(-4.18/T1))/SUMC                             TRAN1740
      GO TO 594                                                         TRAN1750
  588 ZZHV=10.9                                                         TRAN1760
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1770
      SGN=(5.16E-17  *EXP(-3.50/T1))/SUMN                               TRAN1780
      GO TO 596                                                         TRAN1790
  589 ZZHV=11.6                                                         TRAN1800
```

```
                                                                        TRAN1810
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1820
      SGN2=1.0E-18                                                      TRAN1830
      SGN=(5.16E-17 *  EXP(-3.50))/SUMN                                 TRAN1840
  598 SGC=(9.9E-17  +  8.5E-17 * EXP(-1.26/T1)  +2.2E-17 * EXP(-2.75/T1)TRAN1850
     1      +  5.0E-17 * EXP(-4.18/T1))/SUMC                            TRAN1860
      IF (K.LT.11) GO TO 594                                            TRAN1870
      GO TO 38                                                          TRAN1880
  590 ZZHV=12.7                                                         TRAN1890
      CALL ZHV  (ZZHV,ZZC,ZZN,ZZI,ZZC)                                  TRAN1900
      SGN2=2.0E-18                                                      TRAN1910
      SGH2 =  2.7E-17                                                   TRAN1920
  599 SGN=(6.4E-17 * EXP(-2.30/T1)   +   5.16E-17 * EXP(-3.50/T1))/SUMN  TRAN1930
     1      +  SGN                                                      TRAN1940
      GO TO 598                                                         TRAN1950
  591 SGH=1.18E-17/SUMH                                                 TRAN1960
      SGO=3.6E-17/SUMO                                                  TRAN1970
      SGN2=1.0E-17                                                      TRAN1980
      SGH2 =  2.7E-17                                                   TRAN1990
      GO TO 599                                                         TRAN2000
  592 SGN=3.6E-17/SUMN                                                  TRAN2010
      SGN2=1.0E-18                                                      TRAN2020
      GO TO 599                                                         TRAN2030
   38 CONTINUE                                                          TRAN2040
      FMUC(K,L)=  SNDH(L)*SGH + SNDC(L)*SGC + SNDN(L)*SGN + SNDO(L)*SGO  TRAN2050
                + XMCL *      (SNDN2(L)*SGN2 + SNDO2(L)*SGO2 +          TRAN2060
     1            SNDC2(L)*SGC2 + SNDH2(L)*SGH2 + SNDCO(L)*SGCO +       TRAN2070
     2            SNDC3(L)*SGC3 +SNDC2H(L)*SGC2H )                      TRAN2080
     3                                                                  TRAN2090
      IF (L.GT.1) GO TO 8                                               TRAN2100
      TAUC(K,L)=0.                                                      TRAN2110
      GO TO 5                                                           TRAN2120
    8 TAUC(K,L)=TAUC(K,L-1)+(YD(L)-YD(L-1))*                            TRAN2130
     1      (FMUC(K,L-1)+FMUC(K,L)) * DELTA                             TRAN2140
    5 CONTINUE                                                          TRAN2150
      IF (LINES.EQ.0) GO TO 91                                          TRAN2160
C
C **   FRACTIONAL POPULATION STATES FOR H. N. O. C  **
```

```
C                                                                        TRAN2170
      CALL ZP (T1.SUMN.SUMO.SUMH.SUMC)                                   TRAN2180
C **   CALCULATION OF PARAMETERS FOR 9 LINE GROUPES   **                 TRAN2190
C      WN -- NUMBER OF LINES                                             TRAN2200
C      FG -- EFFECTIVE F-NUMBER                                          TRAN2210
C      GP -- EFFECTIVE HALF-WIDTH                                        TRAN2220
C                                                                        TRAN2230
C GROUP 1                                                                TRAN2240
      FG(1.2)=(1.02 * ZPC(5)  +  .795 * ZPC(6)  +  0.114 * ZPC(7))       TRAN2250
     1   /WN(1.2)                                                        TRAN2260
      GP(1.2)=(8.16E-11 * SQRT(ZPC(5))  +  1.25E-10 * SQRT(ZPC(6))       TRAN2270
     1     +2.5E-10 * SQRT(ZPC(7)))**2 /(FG(1.2)* WN(1.2)**2)            TRAN2280
      FG(1.3)=(1.04C * ZPN(4)  +  1.29 * ZPN(5)  +  0.C0 *ZPN(6))        TRAN2290
     1        /WN(1.3)                                                   TRAN2300
      GP(1.3)=(6.65E-11 * SQRT(ZPN(4))  +  1.71E-10 * SQRT(ZPN(5))       TRAN2310
     1      +  C.CCE-10 * SQRT(ZPN(6)))**2/(FG(1.3) * WN(1.3)**2)        TRAN2320
      FG(1.4)=(1.C0 * ZPC(5)  +  .978 * ZPC(6))/WN(1.4)                  TRAN2330
      GP(1.4)=(3.90E-11 * SQRT(ZPC(5))  +  9.68E-11 * SQRT(ZPO(6)))**2   TRAN2340
     1        /(FG(1.4) * WN(1.4)**2)                                    TRAN2350
      FMUL(1.L)=FMUC(1.L)                                                TRAN2360
C GROUP 2                                                                TRAN2370
      FG(2.1)=0.805 * ZPH(2)/WN(2.1)                                     TRAN2380
      GP(2.1)=2.37E-10 * 2.37E-10 * ZPH(2)/(FG(2.1) * WN(2.1)**2)        TRAN2390
      FG(2.2)=(C.CCE-2 * ZPC(5)  +  6.71E-2 * ZPC(6))/WN(2.2)            TRAN2400
      GP(2.2)=(C.COE-12 * SQRT(ZPC(5))  +  7.15E-11 * SQRT(ZPC(6)))**2   TRAN2410
     1        /(FG(2.2) * WN(2.2)**2)                                    TRAN2420
      FG(2.3)=(C.C47* ZPN(4)  +  2.85E-2 * ZPN(5))/WN(2.3)               TRAN2430
      GP(2.3)=(1.11E-10 * SQRT(ZPN(4))  +  6.07E-11 * SQRT(ZPN(5)))**2   TRAN2440
     1        /(FG(2.3) * WN(2.3)**2)                                    TRAN2450
      FG(2.4)=(.0217 * ZPC(4)  +  8.25E-2 * ZPO(5))/WN(2.4)              TRAN2460
      GP(2.4)=(2.61E-11 * SQRT(ZPC(4))  +  7.19E-11 * SQRT(ZPO(5)))**2   TRAN2470
     1   /(FG(2.4) * WN(2.4)**2)                                         TRAN2480
      FMUL(2.L)=FMUC(1.L)                                                TRAN2490
C   GROUP 3                                                              TRAN2500
      FG(3.2)=(7.29E-2 * ZPC(2)  +  6.76E-2 *ZPC(3))/WN(3.2)             TRAN2510
      GP(3.2)=(9.08E-12 * SQRT(ZPC(2))  +  8.75E-12 * SQRT(ZPC(3)))**2   TRAN2520
```

```
     1         /(FG(3.2) * WN(3.2)**2)
      FMUL(3.L)=FMUC(2.L)
C   GROUP 4
      FG(4.2)=(1.05 * ZPC(1)   +   1.10E-2 *ZPC(2)   +   0.150 * ZPC(3))
     1         /WN(4.2)
      GP(4.2)=(9.57E-12 * SQRT(ZPC(1))   +   4.86E-12 * SQRT(ZPC(2))
     1         +  5.93E-10 * SQRT(ZPC(3)))**2/(FG(4.2) * WN(4.2)**2)
      FG(4.3)=( 7.40E-2  * ZPN(2)   +   6.34E-2 * ZPN(3))/WN(4.3)
      GP(4.3)=(8.22E-12 * SQRT(ZPN(2))   +   7.60E-12 * SQRT(ZPN(3)))**2
     1         /(FG(4.3) * WN(4.3)**2)
      FMUL(4.L)=FMUC(4.L)
C   GROUP 5
      FG(5.2)=(0.329 * ZPC(1)   +   0.118 * ZPC(2)   +   0.226 * ZPC(4))
     1         /WN(5.2)
      GP(5.2)=(3.65E-11 * SQRT(ZPC(1))   +   5.77E-10 * SQRT(ZPC(2))
     1         +  6.56E-11 *  SQRT(ZPC(4)))**2/(FG(5.2) * WN(5.2)**2)
      FG(5.3)=0.108 * ZPN(3)/WN(5.3)
      GP(5.3)=3.09E-11 * 3.09E-11 * ZPN(3)/(FG(5.3) * WN(5.3)**2)
      FG(5.4)=4.71E-2 * ZPO(1)/WN(5.4)
      GP(5.4)=5.08E-12 * 5.08E-12 * ZPO(1)/(FG(5.4) * WN(5.4)**2)
      FMUL(5.L)=FMUC(6.L)
C   GROUP 6
      FG(6.1)=0.416 * ZPH(1)/WN(6.1)
      GP(6.1)=3.02E-11 * 3.02E-11 * ZPH(1)/(FG(6.1)* WN(6.1)**2)
      FG(6.2)=8.65E-2 * ZPC(1)/WN(6.2)
      GP(6.2)=2.35E-10 * 2.35E-10 * ZPC(1)/(FG(6.2) * WN(6.2)**2)
      FG(6.3)=(0.184 * ZPN(1)   +   0.290 * ZPN(2)   +   8.52E-2 * ZPN(3))
     1         /WN(6.3)
      GP(6.3)=(1.07E-11 * SQRT  (ZPN(1))   +   4.28E-11 * SQRT( ZPN(2))
     1         +  2.09E-10 * SQRT(ZPN(3)))**2/(FG(6.3) * WN(6.3)**2)
      FG(6.4)=(.120 * ZPO(2)   +   0.151 * ZPC(3))/WN(6.4)
      GP(6.4)=(8.85E-12 * SQRT(ZPC(2))   +   9.93E-12 * SQRT(ZPO(3)))**2
     1         /(FG(6.4) * WN(6.4)**2)
      FMUL(6.L)=FMUC(7.L)
C   GROUP  7
      FG(7.2)=(4.51E-2 * ZPC(1)   +   0.705 * ZPC(2))/WN(7.2)
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```
      GP(7.2)=(6.07E-10 * SQRT(ZPC(1))   +   2.10E-10 * SQRT(ZPC(2)))**2   TRAN2890
     1        /(FG(7.2) * WN(7.2)**2)                                      TRAN2900
      FG(7.3)=(C.454 * ZPN(1)   +   9.66E-2 * ZPN(2)                       TRAN2910
     1        +   C.178 * ZPN(3))/WN(7.3)                                  TRAN2920
      GP(7.3)=(2.71E-12 * SQRT(ZPN(1))   +   2.34E-10 * SQRT(ZPN(2))       TRAN2930
     1        +   2.46E-11 * SQRT(ZPN(3)))**2/(FG(7.3)* WN(7.3)**2)        TRAN2940
      FG(7.4)=4.23E-2 * ZPO(3)/WN(7.4)                                     TRAN2950
      GP(7.4)=2.52E-11 * 2.52E-11 * ZPO(3)/(FG(7.4) * WN(7.4)**2)          TRAN2960
      FMUL(7.L)=FMUC(9.L)                                                  TRAN2970
C   GRCUP   8                                                              TRAN2980
      FG(8.1)=0.108 * ZPH(1)/WN(8.1)                                       TRAN2990
      GP(8.1)=1.32E-10   *   1.32E-10 * ZPH(1)                             TRAN3000
     1        /(FG(8.1) * WN(8.1)**2)                                      TRAN3010
      FG(8.2)=(C.379 * ZPC(1)   +   1.C5 * ZPC(3))/WN(8.2)                 TRAN3020
      GP(8.2)=(1.95E-11 * SQRT(ZPC(1))   +   1.27E-10 * SQRT(ZPC(3)))**2   TRAN3030
     1        /(FG(8.2) * WN(8.2)**2)                                      TRAN3040
      FG(8.3)=(0.155 * ZPN(1)   +   C.142*ZPN(2)   +   3.75E-2 * ZPN(3))   TRAN3050
     1        /WN(8.3)                                                     TRAN3060
      GP(8.3)=(2.98E-11 * SQRT(ZPN(1))   +   7.08E-11 * SQRT(ZPN(2))       TRAN3070
     1        +   1.33E-1C * SQRT(ZPN(3)))**2/(FG(8.3) * WN(8.3)**2)       TRAN3080
      FG(8.4)=(0.146 * ZPC(1)   +   8.61E-2*ZPO(2)                         TRAN3090
     1        +   9.33E-2 * ZPO(3))/WN(8.4)                                TRAN3100
      GP(8.4)=(1.97E-10 * SQRT(ZPC(1))   +   1.80E-11 * SQRT(ZPO(2))       TRAN3110
     1        +   8.13E-11 * SQRT(ZPC(3)))**2/(FG(8.4) * WN(8.4)**2)       TRAN3120
      FMUL(8.L)=FMUC(10.L)                                                 TRAN3130
C   GRCUP   9                                                              TRAN3140
      FG(9.2)=2.95 * ZPC(2)/WN(9.2)                                        TRAN3150
      GP(9.2)=5.85E-12 * 5.85E-12 * ZPC(2)/(FG(9.2) * WN(9.2)**2)          TRAN3160
      FG(9.3)=(0.224 * ZPN(1)   +   2.92E-2 * ZPN(2))/WN(9.3)              TRAN3170
      GP(9.3)=(3.41E-10 * SQRT(ZPN(1))   +   1.48E-10 * SQRT(ZPN(2)))**2   TRAN3180
     1        /(FG(9.3) * WN(9.3)**2)                                      TRAN3190
      FG(9.4)=(5.24E-2 * ZPO(1)   +   7.22E-2 * ZPO(2)                     TRAN3200
     1        +   6.C4E-2 * ZPO(3))/WN(9.4)                                TRAN3210
      GP(9.4)=(5.76E-12 * SQRT(ZPC(1))   +   7.20E-11 * SQRT(ZPO(2))       TRAN3220
     1        +   8.05E-11 * SQRT(ZPO(3)))**2/(FG(9.4) * WN(9.4)**2)       TRAN3230
      FMUL(9.L)=FMUC(11.L)                                                 TRAN3240
```

```
C
C **   PLANCK FUNCTION  **
C
      DO 9 J=1,NHVL
      BEEL(J,L)=5.04E3 * HVJ(J)**3 / (EXP(HVJ(J)/T1)  -  1.0)
C
C **   INDUCED EMISSION FACTOR (EQ 81)   **
C
      SSM(J,1,L)=1.10E-16*SNDH (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,1)
      SSM(J,2,L)=1.10E-16*SNDC (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,2)
      SSM(J,3,L)=1.10E-16*SNCN (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,3)
      SSM(J,4,L)=1.10E-16*SNDO (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,4)
      DO 10 M=1,4
      GGM(J,M,L)=GP(J,M) * SNDE(L)    * (T(L)/1.0E4)**0.25
     1         +  1.0E-6
      IF(L.GT.1) GO TO 11
      ETAM(J,M,1)=0.
      SBM (J,M,1)=0.
      GO TO 10
   11 ETAM(J,M,L)=ETAM(J,M,L-1)+  (YD(L)-YD(L-1))
     1         *(SSM(J,M,L-1) * GGM(J,M,L-1)  +  SSM(J,M,L) * GGM(J,M,L))
     2         * DELTA/3.14159265
      SBM(J,M,L)=SBM(J,M,L-1)  +  (YD(L)-YD(L-1))
     1         * (SSM(J,M,L-1)+SSM(J,M,L)) * DELTA
   10 CONTINUE
      IF (L.GT.1) GO TO 12
      TAUL(J,1)=0.
      GO TO 9
   12 TAUL(J,L)=TAUL(J,L-1)   +  (YD(L)-YD(L-1))
     1         * (FMUL(J,L-1)+FMUL(J,L))  * DELTA
    9 CONTINUE
      IF (IDG.NE.99) GO TO 91
      CALL BUGPR (7)
C
   91 CONTINUE
      IEZ=IEZ+1
```

```
      ETZ(IEZ)=1.C                                                      TRAN3610
C                                                                       TRAN3620
C **   CONTINUUM - CONTINUUM FLUX DIVERGENCE CALCULATION  **             TRAN3630
C                                                                       TRAN3640
      CO 300 K=1.IEZ                                                    TRAN3650
      DO 31 LK=1.NES                                                    TRAN3660
      I=LK                                                              TRAN3670
      NUT(K)=I                                                          TRAN3680
      IF (ABS(ETZ(K)-ETA(LK)) - 1.0E-5) 300.300.31                      TRAN3690
   31 CONTINUE                                                          TRAN3700
  300 CONTINUE                                                          TRAN3710
      CO 1612 J=1.9                                                     TRAN3720
      CCLP(J)=0.                                                        TRAN3730
      GLCP(J)=0.                                                        TRAN3740
      GLLP(J)=0.                                                        TRAN3750
      CO 1612 L=1.NES                                                   TRAN3760
      FM(J.L)=0.                                                        TRAN3770
 1612 FP(J.L)=0.                                                        TRAN3780
      CO 1613 L=1.IEZ                                                   TRAN3790
      CCL(L)=C.                                                         TRAN3800
      GLC(L)=C.                                                         TRAN3810
 1613 GLL(L)=C.                                                         TRAN3820
      CO 49 IYY=1.IEZ                                                   TRAN3830
      IY=NUT(IYY)                                                       TRAN3840
      CO 20 K=1.12                                                      TRAN3850
      FMC(K.IY)=0.                                                      TRAN3860
      FPC(K.IY)=C.                                                      TRAN3870
      IF (IY.EQ.1) GO TO 44                                             TRAN3880
      CO 4C L=1.IY                                                      TRAN3890
C                                                                       TRAN3900
C **   MINUS EMISSIVITY FUNCTION (EC 47)   *                            TRAN3910
C                                                                       TRAN3920
      EM(K.L)=1.C  -  EXP(TAUC(K.L)-TAUC(K.IY))                        TRAN3930
      IF (L.EQ.1) GC TO 4C                                              TRAN3940
C                                                                       TRAN3950
C **   MINUS CONTINUUM FLUX (EQ 46)  **                                 TRAN3960
```

```
C                                                                       TRAN3970
      FMC(K,IY)=FMC(K,IY)   -   (EM(K,L)-EM(K,L-1))                     TRAN3980
     1          * (BEEC(K,L-1)+BEEC(K,L))/2.                            TRAN3990
   40 CONTINUE                                                          TRAN4000
   44 IF (IY.EQ.NES ) GO TO 41                                          TRAN4010
      DO 42 L=IY,NES                                                    TRAN4020
C                                                                       TRAN4030
C **   POSITIVE EMISSIVITY FUNCTION (EQ 47)   **                        TRAN4040
C                                                                       TRAN4050
      EP(K,L)=1.0   -   EXP(TAUC(K,IY)-TAUC(K,L))                       TRAN4060
      IF (L.EQ.IY) GO TO 42                                             TRAN4070
C                                                                       TRAN4080
C **   POSITIVE EMISSIVITY CONTINUUM FLUX (EQ 46)   **                  TRAN4090
C                                                                       TRAN4100
      FPC(K,IY)=FPC(K,IY)   +   (EP(K,L)-EP(K,L-1))                     TRAN4110
     1          * (BEEC(K,L-1)+BEEC(K,L))/2.                            TRAN4120
   42 CONTINUE                                                          TRAN4130
C                                                                       TRAN4140
C **   POSITIVE EMISSIVITY CONTINUUM FLUXDIVERGENCE (EQ 51)   **        TRAN4150
C                                                                       TRAN4160
   41 QCCP(K)=6.2831853 * FMUC(K,IY) *                                  TRAN4170
     1          (FMC(K,IY)   +   FPC(K,IY)   -   2.0* BEEC(K,IY))       TRAN4180
      FMC(K,IY)=FMC(K,IY) * 3.14159265                                  TRAN4190
      FPC(K,IY)=FPC(K,IY) * 3.14159265                                  TRAN4200
   20 CONTINUE                                                          TRAN4210
C                                                                       TRAN4220
C **   DEBUG PRINT   **                                                 TRAN4230
C                                                                       TRAN4240
      IF (IDG.NE.99) GO TO 21                                           TRAN4250
      CALL BUGPR (3)                                                    TRAN4260
   21 QCC(IYY)=0.                                                       TRAN4270
      DO 24 K=1,12                                                      TRAN4280
C                                                                       TRAN4290
C **   LINE AND CROSS TERM FLUX DIVERGENCE CALCULATION   **             TRAN4300
C                                                                       TRAN4310
   24 QCC(IYY)=QCC(IYY)   +   QCCP(K)                                   TRAN4320
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                                                                        TRAN4330
      IF (LINES.EQ.0) GO TO 1614                                        TRAN4340
C                                                                       TRAN435C
C **   INTEGRATION FRCM 1 TO IY   **                                    TRAN4360
C                                                                       TRAN4370
      IF (IY.EQ.1) GO TO 68                                             TRAN438C
      DO 65 J=1,9                                                       TRAN439C
      DO 66 L=1,IY                                                      TRAN4400
      WIM=0.                                                            TRAN4410
      SUM1=C.                                                           TRAN4420
      SUM2=0.                                                           TRAN4430
      DO 67 M=1,4                                                       TRAN4440
      DIF=ETAM(J,M,IY)  -  ETAM(J,M,L)                                  TRAN4450
      DIFSBM =      SBM(J,M,IY)-SBM(J,M,L)                              TRAN4460
      IF(ABS(DIFSBM).LT.1.E-10)  DIFSBM = 1.E-10                        TRAN4470
      DETAM=DIF / ( DIFSBM                 )  *  3.14159265             TRAN4480
      IF (L.EQ.IY) BETAM=GGM(J,M,L)                                     TRAN4490
      IF(ABS(DIF).GT.1.E-10) GO TO 9001                                 TRAN4500
      TM = 1.E-10                                                       TRAN4510
      GO TO 9002                                                        TRAN4520
 9001 CONTINUE                                                          TRAN4530
      TM=DIF/2.0/BETAM**2                                               TRAN454C
 9002 RRM=DIF/2.0/GGM(J,M,IY)**2                                        TRAN4550
      WWM=6.2831853 * WN(J,M) * BETAM * GAMMA(TM) * TM                  TRAN456C
      SUM1=SUM1  +  GAMMA(TM) * WN(J,M) * SSM(J,M,IY)                   TRAN4570
      SUM2=SUM2  +  XLAMB(RRM) * WN(J,M) * SSM(J,M,IY)                  TRAN458C
   67 WIM=WIM  +  WWM                                                   TRAN4590
      ALPHAM=WIM/DJ(J)                                                  TRAN4600
C                                                                       TRAN461C
C **   OVERLAPPING LINE CALCULATIONS  **                                TRAN462C
C                                                                       TRAN4630
C                                                                       TRAN4640
C **   GROUP EQUIVALENT WIDTHS  (EQ.88)  **                             TRAN4650
C                                                                       TRAN466C
      WMM(J,L)=DJ(J) * PHI1(ALPHAM) * EXP(TAUL(J,L)-TAUL(J,IY))         TRAN4670
C                                                                       TRAN4680
C **   GROUP GAMMA -- LINE TRANSPORT FUNCTION (EQ.92)  **
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C                                                                       TRAN4690
      GMM(J,L)=PHI2(ALPHAM) * SUM1                                      TRAN4700
C                                                                       TRAN4710
C **   MINUS EMISSIVITY FUNCTION FOR LINES (EQ.47)  **                  TRAN4720
C                                                                       TRAN4730
      EEM(J,L)=1.0  -  EXP(TAUL(J,L)-TAUL(J,IY))                        TRAN4740
   66 XLMM(J,L)=PHI2(ALPHAM) * SUM2                                     TRAN4750
   65 CONTINUE                                                          TRAN4760
      IF (IDG.EQ.99) CALL BUGPR(1)                                      TRAN4770
      IF (IDG.EQ.99) CALL BUGPR (4)                                     TRAN4780
   68 IF (IY.EQ.NES) GO TO 72                                           TRAN4790
C                                                                       TRAN4800
C **   INTEGRATION FROM IY TO NES  **                                   TRAN4810
C                                                                       TRAN4820
      DO 69 J=1,9                                                       TRAN4830
      DO 70 L=IY,NES                                                    TRAN4840
      WIP=0.                                                            TRAN4850
      SUM1=0.                                                           TRAN4860
      SUM2=0.                                                           TRAN4870
      DO 71 M=1,4                                                       TRAN4880
      DIF=ETAM(J,M,L)  -  ETAM(J,M,IY)                                  TRAN4890
      DIFSBM =      SBM(J,M,L)-SBM(J,M,IY)                              TRAN4900
      IF(ABS(DIFSBM).LT.1.E-10)  DIFSBM = 1.E-10                        TRAN4910
      BETAP=DIF / ( DIFSBM                ) * 3.14159265                TRAN4920
      IF (L.EQ.IY) BETAP=GGM(J,M,L)                                     TRAN4930
      IF(ABS(DIF).GT.1.E-10) GO TO 9003                                 TRAN4940
      TP = 1.E-10                                                       TRAN4950
      GO TO 9004                                                        TRAN4960
 9003 CONTINUE                                                          TRAN4970
      TP=DIF/2.0/BETAP**2                                               TRAN4980
 9004 RRP=DIF/2.0/GGM(J,M,IY)**2                                        TRAN4990
      WWP=6.2831853 * WN(J,M) * BETAP * GAMMA(TP) * TP                  TRAN5000
      SUM1=SUM1  +  GAMMA(TP) * WN(J,M) * SSM(J,M,IY)                   TRAN5010
      SUM2=SUM2  +  XLAMB(RRP) * WN(J,M) * SSM(J,M,IY)                  TRAN5020
   71 WIP=WIP+WWP                                                       TRAN5030
      ALPHAP=WIP/DJ(J)                                                  TRAN5040
```

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      WPP(J,L)=DJ(J) * PHI1(ALPHAP) * EXP(TAUL(J,IY)-TAUL(J,L))
      GPP(J,L)=PHI2(ALPHAP) * SUM1
C
C **   POSITIVE EMISSIVITY FUNCTION FOR LINES (EQ.47)   **
C
      EEP(J,L)=1.0  -  EXP(TAUL(J,IY)-TAUL(J,L))
   70 XLPP(J,L)=PHI2(ALPHAP) * SUM2
   69 CONTINUE
C
C **   DEBUG PRINT  **
      IF (IDG.EQ.99) CALL BUGPR (5)
C
   72 DO 80 J=1,9
      ASM1=0.
      ASM2=0.
      FM(J,IY)=0.
      IF (IY.EQ.1) GO TO 81
      DO 82 L=2,IY
      FM(J,IY)=FM(J,IY)  -  (WMM(J,L)-WMM(J,L-1))
     1         *(BEEL(J,L-1)+BEEL(J,L)) * 1.5707963
      IF (L.EQ.IY) GO TO 82
      ASM1=ASM1  -  (EEM(J,L)-EEM(J,L-1))
     1         * (BEEL(J,L-1) * XLMM(J,L-1) + BEEL(J,L) * XLMM(J,L))/2.
      ASM2=ASM2  -  (XLMM(J,L)-XLMM(J,L-1))
     1         * (BEEL(J,L-1) * EXP(TAUL(J,L-1)-TAUL(J,IY)) + BEEL(J,L)
     2         * EXP(TAUL(J,L)-TAUL(J,IY)))/2.0
   82 CONTINUE
   81 ASP1=0.
      ASP2=0.
      IYP=IY+1
      IF (IY.EQ.NES) GO TO 83
      DO 84 L=IYP,NES
      FP(J,IY)=FP(J,IY)  +  (WPP(J,L)-WPP(J,L-1))
     1         * (BEEL(J,L-1)+BEEL(J,L)) * 1.5707963
      IF (L.EQ.IYP) GO TO 84
      ASP1=ASP1  +  (EEP(J,L)-EEP(J,L-1))
```

```
     1          * (BEEL(J,L-1) * XLPP(J,L-1) + BEEL(J,L) * XLPP(J,L))/2.0 TRANS410
      ASP2=ASP2  +  (XLPP(J,L)-XLPP(J,L-1)) *                            TRANS420
     1          (BEEL(J,L-1) * EXP(TAUL(J,IY)-TAUL(J,L-1))  +  BEEL(J,L)  TRANS430
     2          * EXP(TAUL(J,IY)-TAUL(J,L)))/2.0                          TRANS440
   84 CONTINUE                                                            TRANS450
   83 GLCP(J)=2.C * FMUL(J,IY) * (FM(J,IY)+FP(J,IY))                      TRANS460
      SUMS=1.C                                                            TRANS470
      SUMT=0.                                                             TRANS480
      DO 86 M=1,4                                                         TRANS490
   86 SUMT=SUMT  +  SSN(J,M,IY) * WN(J,M)                                 TRANS55CC
      ATM1=0.                                                             TRANS5510
      IF (IY.NE.1) ATM1=(BEEL(J,IY-1)+BEEL(J,IY)) /2.0 * EEM(J,IY-1)      TRANS5520
     1          * XLMM(J,IY-1)                                            TRANS5530
      ATP1=0.                                                             TRANS554C
      IF(IY.NE.NES) ATP1=(BEEL(J,IY+1)+BEEL(J,IY))/2.0 * EEP(J,IY+1)      TRANS555C
     1          * XLPP(J,IY+1)                                            TRANS5560
      GCLP(J)=6.2831853  * SUMS * (ASM1+ASP1+ATM1+ATP1)                   TRANS557C
      IF (IY.EQ.1) ATM2=-BEEL(J,IY) * SUMT                                TRANS5580
      IF (IY.NE.1) ATM2=(BEEL(J,IY-1)-BEEL(J,IY))  *  GMM(J,IY-1)         TRANS559C
     1          -  BEEL(J,IY-1) * XLMM(J,IY-1)                            TRANS56CC
      IF (IY.EQ.NES) ATP2=-BEEL(J,IY) * SUMT                              TRANS561C
      IF (IY.NE.NES)ATP2=(BEEL(J,IY+1)-BEEL(J,IY))  * GPP(J,IY+1)         TRANS5620
     1          -  BEEL(J,IY+1) * XLPP(J,IY+1)                            TRANS563C
      GLLP(J)=6.2831853 * SUMS*(-ASM2-ASP2+ATM2+ATP2)                     TRANS5640
   80 CONTINUE                                                            TRANS5650
      GCL(IYY)=C.                                                         TRANS5660
      GLC(IYY)=0.                                                         TRANS5670
      GLL(IYY)=C.                                                         TRANS5680
      DO 85 J=1,9                                                         TRANS5690
      GCL(IYY)=GCL(IYY)  +  GCLP(J)                                       TRANS57C0
      GLC(IYY)=GLC(IYY)  +  GLCP(J)                                       TRANS5710
   85 GLL(IYY)=GLL(IYY)  +  GLLP(J)                                       TRANS5720
 1614 CONTINUE                                                            TRANS5730
      CON(IYY)=-(GCC(IYY)+GCL(IYY)+GLC(IYY)+GLL(IYY))                     TRANS5740
C                                                                         TRANS5750
C **   DEBUG PRINT  **                                                    TRANS5760
```

```
C                                                                 TRAN5770
      IF (IDG.EQ.0) GO TO 49                                      TRAN5780
      CALL BUGPR(6)                                               TRAN5790
   49 CONTINUE                                                    TRAN5800
      IEZ=IEZ-1                                                   TRAN5810
      DQ(1)=DQN(1)                                                TRAN5820
      L=2                                                         TRAN5830
      DO 1 N=2,NES                                                TRAN5840
      DO 2 I=2,IEZ                                                TRAN5850
      NP=I                                                        TRAN5860
      IF (ETZ(I).GT.ETA(N)) GO TO 3                               TRAN5870
    2 CONTINUE                                                    TRAN5880
    3 NN=NP-1                                                     TRAN5890
      AA=0.0                                                      TRAN5900
      ZB=(DQN(NN)-DQN(NP)) / (ETZ(NN)-ETZ(NP))                    TRAN5910
      CC=DQN(NN)  -  ZB * ETZ(NN)                                 TRAN5920
      DQ(N)=AA * ETA(N)**2  +  ZB * ETA(N)  +  CC                 TRAN5930
      GO TO 1                                                     TRAN5940
    4 DQ(N)=DQN(NN)                                               TRAN5950
    1 CONTINUE                                                    TRAN5960
      RETURN                                                      TRAN5970
      END                                                         TRAN5980
```

```
      SUBROUTINE SND(I,K)
      COMMCN /PRCP/ P(60),     R(6C),                     T(60)
      COMMCN /MOLFRA/    X1(60),X2(6C),    X3(60),    X4(60),
     1                        X7(6C),   X8(60),   X9(60),   X10(60),
     2                  X11(6C),  X12(60), X13 (60), X14(60)
      COMMON /RFLUX/ ANW(60),  IRAD,  ITYPE,  E(60)
      COMMCN /NCN/ RDZ,  MLDZ,  RNDZ
      COMMON /NUMDEN/ SNDO2(60), SNDN2(6C), SNDO(60), SNDN(60),
     1                                    SNDE(60), SNDC(60),
     2               SNDH(60), SNDC2(6C), SNDH2(60), SNDCO(60),
     3               SNDC3(60),SNDC2H(6C)
C  **  CALCULATE SPECIE NUMBER DENSITIES BASED ON MOLE FRACTIONS  **
C
      RRUCKM=3.11E+23 * R(I) * RDZ/ANW(I)
C
      SNDO2(I)=RRUCKM * X1(I)
      SNDN2(I)=RRUCKM * X2(I)
      SNDC(I)=RRUCKM * X3(I)
      SNDN(I)=RRUCKM * X4(I)
      SNDE(I)=RRUCKM * X7(I)
      SNDC(I)=RRUCKM * X8(I)
      SNDH(I)=RRUCKM * X9(I)
      SNDC2(I)=RRUCKM * X10(I)
      SNDH2(I)=RRUCKM * X11(I)
      SNDCO(I)=RRUCKM * X12(I)
      SNDC3(I)=RRUCKM * X13(I)
      SNDC2H(I)=RRUCKM * X14(I)
      RETURN
      END
```

```
      SUBROUTINE ZP(T1,SUMN,SUMO,SUMH,SUMC)
C
C     **  FRACTIONAL POPULATION STATES FOR N, O, H, C  **
C
      COMMON /ZPI/ ZPO(6), ZPN(6),ZPH(2),  ZPC(7)
      ZPH(1)=2.0/SUMH
      ZPH(2)=8.0 * EXP(-10.20/T1)/SUMH
      ZPC(1)=9.0/SUMC
      ZPC(2)=5.0 * EXP(-1.264/T1)/SUMC
      ZPC(3)=EXP(-2.684/T1)/SUMC
      ZPC(4)=5.0 * EXP(-4.183/T1)/SUMC
      ZPC(5)=12.0 * EXP(-7.532/T1)/SUMC
      ZPC(6)=36.0*EXP(-8.722/T1)/SUMC
      ZPC(7)=60.0 * EXP(-9.724/T1)/SUMC
      ZPN(1)=4.0/SUMN
      ZPN(2)=10.0* EXP(-2.384/T1)/SUMN
      ZPN(3)=6.0 * EXP(-3.576/T1)/SUMN
      ZPN(4)=18.0 * EXP(-10.452/T1)/SUMN
      ZPN(5)=54.0 * EXP(-11.877/T1)/SUMN
      ZPN(6)=90.0 * EXP(-13.002/T1)/SUMN
      ZPO(1)=9.0/SUMO
      ZPO(2)=5.0 * EXP(-1.967/T1)/SUMO
      ZPO(3)=EXP(-4.188/T1)/SUMO
      ZPO(4)=8.0 * EXP(-9.283/T1)/SUMO
      ZPO(5)=24.0 * EXP(-10.830/T1)/SUMO
      ZPO(6)=40.0 * EXP(-12.077/T1)/SUMO
C
      RETURN
      END
```

```
      SUBROUTINE TRANS2
      COMMON /SFLUX/ QRI(3)
      COMMON /XY/  ETA(60)
      COMMON /FRSTRM/    U INF,    RINF,     UINF2,    XL,  RE,  LXI,
     1                   ITM,      ITG,      NES
      COMMON /TRN/ YD(60),NUT(60), FMC(12,60), FPC(12,60),
     1           FM(9,60), FP(9,60), LINES
      COMMON /FINV/ NHVL,NIHVC,FHVC(12),CJ(9),HVJ(9),ZKZ
      COMMON /TEST/ETZ(60),IEZ
      COMMON /NUMDEN/ SNDC2(60), SNDN2(60), SNDO(60), SNDN(60),
     1                                     SNDE(60), SNDC(60),
     2                SNDH(60), SNDC2(60), SNDH2(60), SNDCO(60),
     3                SNDC3(60),SNDC2H(60)
      COMMON /SPEC/ MF, XMOL
      DIMENSION ETOUT(3)
      NETA=NES
      ETOUT(1)=0.0
C
      ETOUT(2)=0.5
C
      ETOUT(3)=1.0
      NOUT=3
C
C   OUTPUT FLUX
C
      WRITE (6,600)
      WRITE (6,603) (ETA(I),SNDN2(I),SNDC2(I),SNDN(I),SNDO(I),
     1                         SNDE(I), SNDC(I), I=1,NETA)
      WRITE (6,602)
      WRITE (6,601) (ETA(I),SNDH(I),SNDC2(I),SNDH2(I),SNDCO(I),SNDC3(I),
     1            SNDC2H(I),                    I=1,NETA)
C **   CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX **
C
      WRITE (6,4103)
      DO 8040 K=1,NOUT
      DO 8041 LK=1,NES
```

```
      NUT(K)=LK
      IF (ABS(ETOUT(K)-ETA(LK)) - 1.0E-05) 8040,8040,8041
 8041 CONTINUE
 8040 CONTINUE
      L1=NUT(1)
      L2=NUT(2)
      L3=NUT(3)
      WRITE (6,8037)(ETOUT(IL),IL=1,3)
      FM1=0.0
      FP1=0.0
      FM2=0.0
      FP2=0.0
      FM3=0.0
      FP3=0.0
      DO 4104 KL=1,NIHVC
      WRITE (6,8042) KL,   FHVC(KL),   FMC(KL,L1),   FPC(KL,L1),
     1             FMC(KL,L2),   FPC(KL,L2),  FMC(KL,L3),   FPC(KL,L3)
      FM1=FM1   +  FMC(KL,L1)
      FP1=FP1   +  FPC(KL,L1)
      FM2=FM2   +  FMC(KL,L2)
      FP2=FP2   +  FPC(KL,L2)
      FM3=FM3   +  FMC(KL,L3)
      FP3=FP3   +  FPC(KL,L3)
 4104 CONTINUE
      WRITE (6,8045) FM1,   FP1,   FM2,   FP2,   FM3,   FP3
      QRI(1)=FM1+FP1
      QRI(2)=FM2+FP2
      QRI(3)=FM3+FP3
C
C **   LINE      CONTRIBUTION TO THE SPECTRAL FLUX **
C
      IF (LINES.EQ.0) RETURN
      WRITE (6,8035)
      WRITE (6,8037) (ETOUT(IL),IL=1,3)
      FM1=0.0
      FP1=0.0
```

```
      FM2=0.0                                                           TRAN 730
      FP2=0.0                                                           TRAN 740
      FM3=0.0                                                           TRAN 750
      FP3=0.0                                                           TRAN 760
C                                                                       TRAN 770
C **   TOTAL FLUX CALCULATION   **                                      TRAN 780
C                                                                       TRAN 790
      DO 8043 KL=1,NHVL                                                 TRAN 800
      WRITE (6,8042) KL,   HVJ(KL),   FM(KL,L1),   FP(KL,L1),           TRAN 810
     1            FM(KL,L2),   FP(KL,L2),   FM(KL,L3),   FP(KL,L3)      TRAN 820
      FM1=FM1   +  FM(KL,L1)                                            TRAN 830
      FP1=FP1   +  FP(KL,L1)                                            TRAN 840
      FM2=FM2   +  FM(KL,L2)                                            TRAN 850
      FP2=FP2   +  FP(KL,L2)                                            TRAN 860
      FM3=FM3   +  FM(KL,L3)                                            TRAN 870
      FP3=FP3   +  FP(KL,L3)                                            TRAN 880
 8043 CONTINUE                                                          TRAN 890
      WRITE (6,8045) FM1,   FP1,   FM2,   FP2,   FM3,   FP3             TRAN 900
      GRI(1)=GRI(1)   +   FM1   +   FP1                                 TRAN 910
      GRI(2)=GRI(2)   +   FM2   +   FP2                                 TRAN 920
      GRI(3)=GRI(3)   +   FM3   +   FP3                                 TRAN 930
C                                                                       TRAN 940
  600 FORMAT (1H1,33HNUMBER DENSITIES  (PARTICLES/CM3) ///5X,3HETA,12X, TRAN 950
     1        2HC2,11X,2HN2,11X,1HC,12X,1HN,12X,                 2HE-,  TRAN 960
     2        12X,1HC //)                                               TRAN 970
  601 FORMAT (1P7E13.4)                                                 TRAN 980
  602 FORMAT (1H1,33HNUMBER DENSITIES  (PARTICLES/CM3) ///5X,3HETA,12X, TRAN 990
     1        1HH,12X,2HC2,11X,2HH2,11X,2HCO,11X,2HC3,11X,3HC2H///)     TRAN1000
  603 FORMAT (1P7E13.4)                                                 TRAN1010
 4103 FORMAT (44H1CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX)          TRAN1020
 8035 FORMAT (39HOLINE CONTRIBUTION TO THE SPECTRAL FLUX)               TRAN1030
 8037 FORMAT (/22X,5HETA =F7.3,13X,5HETA =F7.3,13X,5HETA =F7.3//3X,1HI, TRAN1040
     1 3X,3HHNU,8X,6HQMINUS,7X,5HQPLUS,8X,6HQMINUS,7X,5HQPLUS,8X,       TRAN1050
     2 6HQMINUS,7X,5HQPLUS/)                                            TRAN1060
 8042 FORMAT (I4,F8.3,1P8E13.3)                                         TRAN1070
 8045 FORMAT (12HOTOTAL FLUX ,1P8E13.3)                                 TRAN1080
```

```
      RETURN                                                  TRAN1090
      END                                                     TRAN1100
```

```
      SUBROUTINE BUGPR (IDGSW)
      COMMON /FRSTRM/    U INF,     RINF,      UINF2,     XL,  RE,  LXI,
     1                   ITM,       ITG,       NES
      COMMON /XY/  ETA(60)
      COMMON /TRN/ YD(60),NUT(60), FMC(12,60), FPC(12,60),
     1             FM(9,60),  FP(9,60), LINES
      COMMON /DBUG/ QLC(60), QCL(60), QLL(60), DQN(60), QCC(60),
     1             BEEC(12,60),   FMUC(12,60),   EM(12,60),
     2             EP(12,60),     TAUC(12,60),   BEEL(9,60),
     3             QCCP(12),      WNM(9,60),     GMM(9,60),
     4             EEM(9,60),     XLNM(9,60),    QLCP(9),
     5             CCLP(9),       QLLP(9),       DELTA,     IY,   IYY,
     6             WPP(9,60),     GPP(9,60),     EEP(9,60),
     7             XLPP(9,60),    FG(9,4),       GP(9,4),   LL,
     8             WN(9,4),       FMUL(9,60),    SSM(9,4,60),
     9             GGM(9,4,60),   ETAM(9,4,60),  SBM(9,4,60),
     A             TAUL(9,60)
      GO TO (10,20,30,40,50,60,70), IDGSW
   10              WRITE (6,194)
  194 FORMAT (1H1)
      RETURN
   20 WRITE (6,7182) DELTA
 7182 FORMAT (7H0DELTA=1PE14.7,3H CM)
      RETURN
   30 WRITE (6,190) IY,    YD(IY)
  190 FORMAT (4H1IY=I3,2X,3HYD=1PE12.5//2X,1HK,2X,1HL,7X,3HETA,13X,2HYD,
     1 13X,2HMU,11X,3HTAU,14X,1HE,11X,3HBEE//)
      DO 22 K=1,12
      IF (IY.EQ.1) GO TO 23
      WRITE(6,191) (K,   L,   ETA(L),   YD(L),   FMUC(K,L),   TAUC(K,L),
     1             EM(K,L),  BEEC(K,L),   L=1,IY)
  191 FORMAT (2I3,1P6E15.5)
      WRITE (6,192)
  192 FORMAT (//)
   23 IF (IY.EQ.NES) GO TO 22
      WRITE (6,191) (K,   L,   ETA(L),   YD(L),   FMUC(K,L),
```

```
 1                TAUC(K,L),   EP(K,L),   BEEC(K,L),   L=IY,NES)        BUGP 370
 22 WRITE (6,193) FMC(K,IY),   FPC(K,IY),   QCCP(K)                    BUGP 380
193 FORMAT (5HCFIM=1PE12.5 ,2X,4HFIP=E12.5,2X,5HQCCP=E12.5)            BUGP 390
    RETURN                                                             BUGP 400
40                  WRITE (6,195) IY,   YD(IY),   ((J,   L,   YD(L),   BUGP 410
  1               WMM(J,L),   GMM(J,L),   XLMM(J,L),   EEM(J,L),       BUGP 420
  2               BEEL(J,L),   L=1,IY),   J=1,9)                       BUGP 430
195 FORMAT (4H0IY=I3,2X,3HYY=1PE12.5//2X,1HJ,2X,1HL,7X,2HYD,12X,3HWMM,BUGP 440
  1 12X,3HGMM,11X,4HXLMM,13X,3HEEM,13X,3HBEE//(2I3,6E16.5))            BUGP 450
    RETURN                                                             BUGP 460
50                  WRITE (6,196) IY,   YD(IY),   ((J,   L,   YD(L),   BUGP 470
  1          WPP(J,L),   GPP(J,L),   XLPP(J,L),   EEP(J,L),            BUGP 480
  2          BEEL(J,L),   L=IY,NES),   J=1,9)                          BUGP 490
196 FORMAT (4H0IY=I3,2X,3HYY=1PE12.5//2X,1HJ,2X,1HL,7X,2HYD,13X,3HWPP,BUGP 500
  1 2X,3HGPP,11X,4HXLPP,13X,3HEEP,13X,3HBEE//(2I3,6E16.5))             BUGP 510
    RETURN                                                             BUGP 520
60  WRITE (6,198) IY,   ETA(IY),   YD(IY)                              BUGP 530
198 FORMAT (4H0IY=I3,2X,4HETA=1PE12.5,2X,3HYY=E12.5//2X,1HJ,5X,3HQCC, BUGP 540
  1 11X,3HFMC,11X,3HFPC,11X,3HQCL,11X,3HQLC,11X,3HQLL,12X,2HFM,12X,   BUGP 550
  2 2HFP,11X,3HDQN//)                                                  BUGP 560
    WRITE (6,199) (J,   QCCP(J),   FMC(J,IY),   FPC(J,IY),             BUGP 570
  1               QCLP(J),   QLCP(J),   QLLP(J),   FM(J,IY),FP(J,IY),  BUGP 580
  2               J=1,9)                                               BUGP 590
199 FORMAT (I3,1P8E14.5)                                               BUGP 600
    WRITE (6,8069) (J,   QCCP(J),   FMC(J,IY),   FPC(J,IY),   J=10,12)BUGP 610
8069 FORMAT (I3,1P3E14.5)                                              BUGP 620
    WRITE (6,200) QCC(IYY),   QCL(IYY),   QLC(IYY),   QLL(IYY),        BUGP 630
  1               DQN(IYY)                                             BUGP 640
200 FORMAT (1H0,2X,1PE14.5,28X,3E14.5,28X,E14.5)                       BUGP 650
    RETURN                                                             BUGP 660
70  CONTINUE                                                           BUGP 670
    N = LL                                                             BUGP 680
    WRITE (6,197) N,   ETA(N),   YD(N),   ((J,   M,   WN(J,M),         BUGP 690
  1               FG(J,M),   GP(J,M),   FMUL(J,N),   TAUL(J,N),        BUGP 700
  2               SSM(J,M,N),   GGM(J,M,N),   ETAM(J,M,N),   SBM(J,M,N),BUGP 710
  3               M=1,4),J=1,9)                                        BUGP 720
```

```
197 FORMAT (3HCL=I3,2X,4HETA=1PE12.5,2X,3HYD=E12.5//2X,1HJ,2X,1HM,7X,
   1 1HN,13X,1HF,13X,1HG,11X,3HFNU,11X,3HTAU,11X,3HSSM,11X,3HGGM,10X,
   2 4HETAM,11X,3HSBM//(2I3,9E14.5))
    RETURN
    END
```

```
      SUBROUTINE ZHV(HV,ZO,ZN,ZI,ZC)
C
C
C  **  THIS SUBROUTINE CALCULATES THE QUANTUM MECHANICAL CORRECTION
C          FACTORS GIVEN A FREQUENCY (HV) **
C
      X= HV
      X2 =X*X
      X3 =X2*X
      X4 =X3*X
      X5 =X4*X
      X6 =X5*X
      X7 =X6*X
      IF (X -9.82) 1,1,2
 1    ZO = .9999795            -.3155480*X          +2.824548 E-02*X2
     1    +6.677328 E-03*X3    -3.644585 E-03*X4    +8.058070 E-04*X5
     2    -7.708637 E-05*X6    +2.668133 E-06*X7
      GO TO 3
 2    ZO = (X/9.82)**3
 3    IF (X -8.35) 4,4,5
 4    ZN = 1.000148            - .4183535 *X        + .1680359 *X2
     1    -9.779458 E-02*X3    +3.354635 E-02*X4    -5.609353 E-03*X5
     2    +4.515535E-04*X6     -1.403585 E-05*X7
      GO TO 6
 5    ZN = (X/8.35)**3
 6    Y = X/4.0
      IF (Y-6.6) 9,9,10
 9    Y2 =Y*Y
      Y3 =Y2*Y
      Y4 =Y3*Y
      Y5 =Y4*Y
      Y6 =Y5*Y
      Y7 =Y6*Y
      ZI = 1.000379            - .2964767 *Y        +7.505242 E-02*Y2
     1    -1.702948E-02*Y3     +3.279554 E-03*Y4    -2.128469 E-04*Y5
      GO TO 11
```

```
10    ZI = (Y/6.6)**3                                                      ZHV( 370
11    IF (X-7.37) 12,12,13                                                 ZHV( 380
12    ZC =   .9974367           - .4341812 *X        +8.531314 E-02*X2     ZHV( 390
     1    -1.393917 E-02*X3    +4.C38545 E-03*X4    -5.426425 E-C4*X5     ZHV( 400
     2     +2.812126 E-05*X6   -3.883530 E-07*X7                          ZHV( 410
      GO TO 14                                                            ZHV( 420
13    ZC = (X/7.37)**3                                                    ZHV( 430
14    RETURN                                                              ZHV( 440
      END                                                                 ZHV( 450
```

```
      SUBROUTINE RADIN
      COMMON /DBUG/ QLC(60), QCL(60), QLL(60), DCN(60), QCC(60),
     1              BEEC(12,60),    FNUC(12,60),    EM(12,60),
     2              EP(12,60),      TAUC(12,60),    BEEL(9,60),
     3              QCCP(12),       WNM(9,60),      GMM(9,60),
     4              EEM(9,60),      XLMM(9,60),     CLCP(9),
     5              CCLP(9),        CLLP(9),        DELTA,     IY,   IYY,
     6              WPP(9,60),      GPP(9,60),      EEP(9,60),
     7              XLPP(9,60),     FG(9,4),        GP(9,4),  LL,
     8              WN(9,4),        FNUL(9,60),     SSM(9,4,60),
     9              GGM(9,4,60),    ETAM(9,4,60),   SBM(9,4,60),
     A              TAUL(9,60)
C  **  GROUP 1   **
      WN(1,1)=0.
      FG(1,1)=0.
      GP(1,1)=0.
      WN(1,2)=18.
      WN(1,3)=15.
      WN(1,4)=5.
C  **  GROUP 2   **
      WN(2,1)=3.0
      WN(2,2)=5.0
      WN(2,3)=11.0
      WN(2,4)=10.
C  **  GROUP 3   **
      WN(3,1)=0.
      FG(3,1)=0.
      GP(3,1)=0.
      WN(3,2)=2.0
      WN(3,3)=0.
      FG(3,3)=0.
      GP(3,3)=0.
      WN(3,4)=0.
      FG(3,4)=0.
      GP(3,4)=0.
C  **  GROUP 4   **
```

```
      WN(4,1)=0.                                                        RADI 370
      FG(4,1)=0.                                                        RADI 380
      GP(4,1)=0.                                                        RADI 390
      WN(4,2)=8.0                                                       RADI 400
      WN(4,3)=2.0                                                       RADI 410
      WN(4,4)=0.                                                        RADI 420
      FG(4,4)=0.                                                        RADI 430
      GP(4,4)=0.                                                        RADI 440
C  **  GROUP 5   **                                                     RADI 450
      WN(5,1)=0.                                                        RADI 460
      FG(5,1)=0.                                                        RADI 470
      GP(5,1)=0.                                                        RADI 480
      WN(5,2)=14.                                                       RADI 490
      WN(5,3)=4.0                                                       RADI 500
      WN(5,4)=1.0                                                       RADI 510
C  **  GROUP 6   **                                                     RADI 520
      WN(6,1)=1.0                                                       RADI 530
      WN(6,2)=4.0                                                       RADI 540
      WN(6,3)=13.0                                                      RADI 550
      WN(6,4)=2.0                                                       RADI 560
C  **  GROUP 7   **                                                     RADI 570
      WN(7,1)=0.                                                        RADI 580
      FG(7,1)=0.                                                        RADI 590
      GP(7,1)=0.                                                        RADI 600
      WN(7,2)=6.0                                                       RADI 610
      WN(7,3)=14.0                                                      RADI 620
      WN(7,4)=3.0                                                       RADI 630
C  **  GROUP 8   **                                                     RADI 640
      WN(8,1)=2.0                                                       RADI 650
      WN(8,2)=2.0                                                       RADI 660
      WN(8,3)=11.                                                       RADI 670
      WN(8,4)=15.                                                       RADI 680
C  **  GROUP 9   **                                                     RADI 690
      WN(9,1)=0.                                                        RADI 700
      FG(9,1)=0.                                                        RADI 710
      GP(9,1)=0.                                                        RADI 720
```

```
      WN(9,2)=1.0                                                       RADI 730
      WN(9,3)=11.                                                       RADI 740
      WN(9,4)=10.                                                       RADI 750
      RETURN                                                            RADI 760
      END                                                               RADI 770
```

```
      BLOCK DATA                                                        CATA  10
      COMMCN /FINV/ NHVL,NIHVC,FHVC(12),DJ(9),HVJ(9),ZKZ                DATA  20
      CATA NHVL /9/, NIHVC /12/                                         DATA  30
      CATA FHVC /5.0,  6.0,  7.0,  8.0, 9.0,  10.0,  10.8, 11.1,        DATA  40
     1           12.0, 13.4, 14.3, 20.0/                                CATA  50
      DATA DJ   /0.6,  2.2,  1.5,  1.65, 1.4,  1.0,   1.2,  1.4,        DATA  60
     1           1.0/                                                   DATA  70
      CATA HVJ  /1.3,  2.7,  5.75,  7.57, 9.1, 10.4,  11.4, 12.7,       DATA  80
     1           13.9/                                                  CATA  90
      CATA ZKZ  /7.26E-16/                                              CATA 100
      END                                                               DATA 110
```

APPENDIX C

References

C.1 Wilson, K. H., "Stagnation Point Analysis of Coupled Viscous-Radiation Flow With Massive Blowing," NASA CR-1548, June 1970.

APPENDIX D

VISRAD 3 COMPUTER PROGRAM

DISCUSSION OF THE PROGRAM

This appendix describes a digital computer program which is designed for prediction of stagnation line viscous and radiative coupled shock layer structure and the resulting heating rates produced by a blunt body during super-orbital entry into planetary atmospheres. Formulation of the problem was presented in Chapter 2 from which the first order stagnation line shock layer equations were derived. The computer program described herein was developed using the stagnation line equations and the implicit finite difference techniques stated in Chapter 4. The regime of atmospheric flight is restricted to the laminar continuum regime and to conditions where thermodynamic equilibrium can be applied. The governing equations include the effects of mass injection of ablation species, radiation cooling, and coupling between convection and radiation. The radiative transport term is evaluated using either of two models. The first one is the emission model described in Chapter 3. The second is a line and continuum band model described in Chapter 3 and Appendix B.

Solutions to this problem are obtained by numerically solving the set of stagnation line thin shock layer equations developed in Chapter 2. Chapter 4 presents the finite-difference method used for both the momentum and energy equations as well as the convergence method and criterion. The entire solution process consists of a complex iteration scheme which is started by assuming initial values

for the solution profiles and then iterating until convergence is obtained.

The VISRAD 3 program utilizes thermodynamic and transport properties of air from Ref. D.1 and thermodynamic properties of air-ablation product mixtures from Ref. D.2 as discussed in Chapter 3. The calculation of these properties were programmed as separate subroutines such that either or both calculations could be made during the solution procedure. Air values for k_T, μ and Cp_T are used throughout the shock layer. An elemental step function is assumed for the elemental species solution. The elemental switch from ablation products to air is made at the stagnation point. Species compositions are then computed using the two methods based on the elemental composition, local temperature and pressure.

The program was designed as a tool for use by thermodynamic engineers for thermal environment prediction studies. It provides an accurate method for analyzing a variety of atmospheric entry heating problems. The following is a summary list of the capabilities included in the VISRAD 3 computer program:

- Stagnation line solutions
- Coupled convective and radiative energy flux calculation
- Line and continuum radiation calculation
- Large or small mass injection rates of ablation species
- Complete equilibrium chemistry

In addition to these basic capabilities, the program is designed so that other options can be added without altering the basic program.

A solution to the elemental continuity equations for binary diffusion has been successfully added to the basic program by Esch (Ref. D.2). Additional modifications which could be incorporated into the program are different diffusion, transport and chemical models.

There are three heating rate options available in the program.

- o Convective heating only
- o Uncoupled convective and radiative heating
- o Coupled convective and radiative heating.

PROGRAM PROCEDURES

The VISRAD 3 computer program was developed using a philosophy of minimizing a users effort and maximizing program flexibility and adaptability. Accordingly, the basic program logic as shown in Fig. D.1 is quite simple. However, these five basic subprograms are supported by 20 subroutines and one function subprogram. Each of these peripheral programs perform specific computational functions thus enabling direct addition or substitution of other subroutines when required.

In order to minimize input requirements, three techniques were used. The first consists of internal initialization of values for temperature, density, viscosity and stand-off distance which are necessary to start the solution procedure. If better guesses are available they may be input as discussed in the next section. The second technique involves internal specification in BLOCK DATA of problem defining parameters such as the elemental composition at the

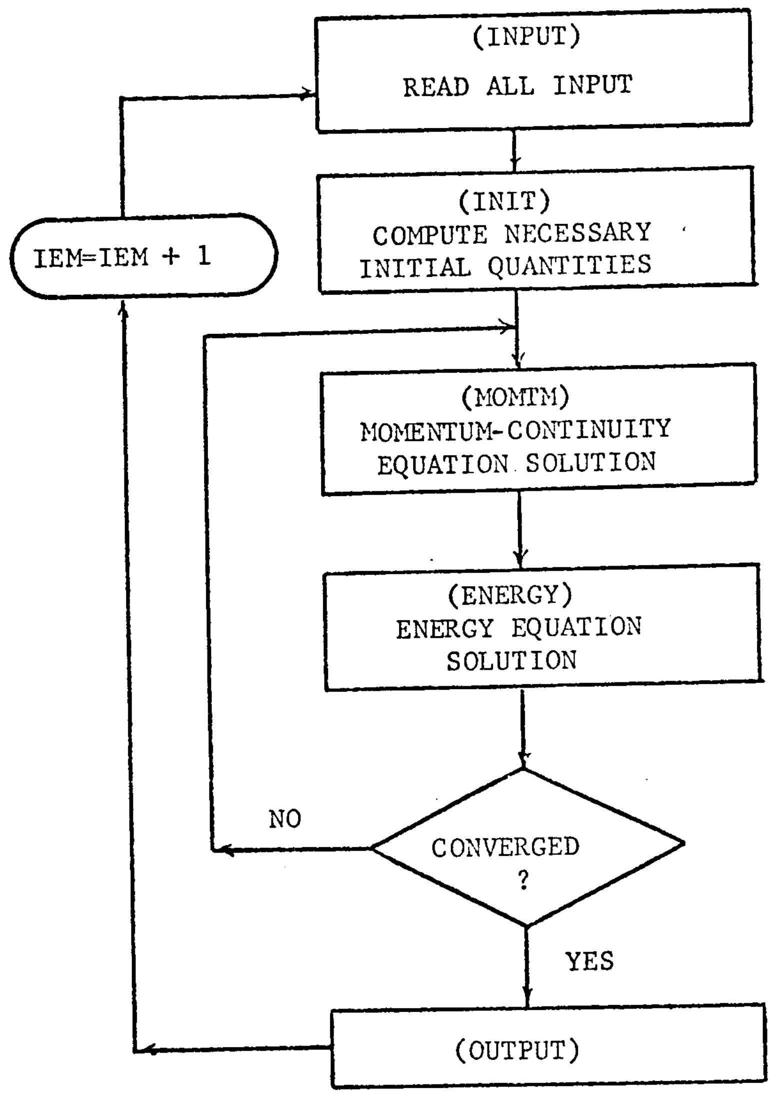

FIGURE D.1 BASIC LOGIC DIAGRAM

surface and the thermodynamic curve-fit constants which are changed quite infrequently. The third technique consists of internally selecting program options if an option variable is left blank on an input card. In this procedure the most commonly used options are performed when a blank is input.

The use of the elemental step function for the solution of the elemental species equation presented one computational difficulty. This type of solution produces a jump in average molecular weight at the stagnation point which results in a discontinuity in density. To eliminate this problem the average molecular weight of the ablation products and that of air was linearly weighted with distance in η near the stagnation point. This is an approximation of the effect diffusion has on the average molecular weight. In this manner the density profile, which is primarily dependent on the temperature, is computed as a smooth function.

The start up of the VISRAD 3 program can be achieved in a number of ways. As stated previously internal guesses are available to begin the iteration procedure. Two types of temperature profiles are available. One for no mass injection and the other for mass injection. These profiles are usually quite satisfactory as initial guesses if an emission radiation coupled problem is to be run. However, if a line and continuum radiation coupled problem which includes mass injection is to be run the internal guess may not be accurate enough. Consequently, a start up logic has been developed to improve the initial guess by beginning the solution procedure using air properties

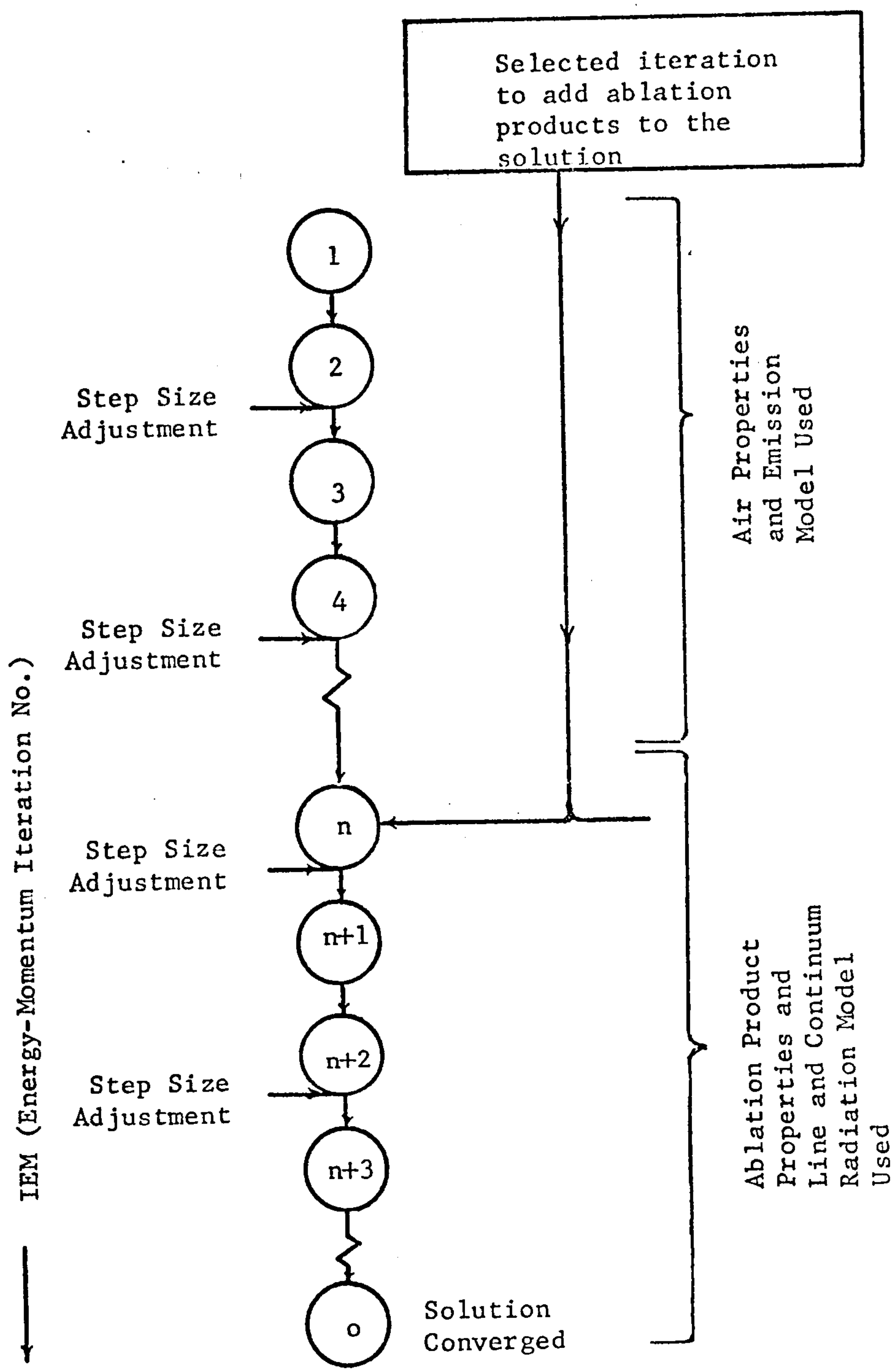

FIGURE D.2 VISRAD 3 Start-up Option Logic

and the emission model. The start up logic is presented schematically in Fig. D.2. The computation procedure is begun with internal guesses and procedes for n-1 iterations as if an air-emission coupled problem is being solved. At the nth iteration the program automatically introduces ablation products and the detailed radiation model into the solution procedure. The n-1th iteration solution profiles are used as initial guesses for the "new" problem. In this way reasonably accurate initial guesses can be achieved with minimal computer time for the specific problem under consideration. The user must select the iteration number at which the switch is to be made. For most problems the simplified solution is nearly established after five or six iterations. The iteration number selected can take on any value from one up. Thus this start up option can be eliminated by introducing the ablation species and detailed radiation at the first iteration. If the iteration number is chosen so large that the switch is never made an air, emission-only solution is obtained. Fig. D.2 also shows the four iteration numbers where a step-size adjustment is made. Since the choice of iteration number for switching ablation and radiation models is arbitrary, some numbers will allow two step-size adjustments to be made at a single IEM iteration (i.e. 2 or 4).

The procedure for step-size adjustment along with the convergence criterion and procedure are presented in detail in Chapter 4 and thus are not discussed here.

INPUT GUIDE

All inputs to the VISRAD 3 computer program are read from cards supplied by the user; no tapes are required. The basic inputs consist

of free-stream velocity and density, principle body radius, wall temperature and mass injection rate. Additional input parameters are needed to determine which program options are desired such as coupled or uncoupled solution, emission or line and continuum radiation model. Four basic formats are used for input, I5, E12.0, E15.8 and A4. Multiple case runs, and hence entire trajectories can be processed by placing the input data for each new case behind the data for the previous one. The entire run is terminated by an end of file.

Tab. D.1 presents the format of the card input and Tab. D.2 provides a corresponding definition of variables.

TABLE D.1

CARD INPUT FOR VISRAD 3

Card	Variables	Format
1	TITLE	18A4
2	KEEP, NETA, IRAD, ITYPE, MAXM, MAXE, MAXD, LT, IPHI, FPRCT, TPRCT, IDEBUG	9I5, 2E12.0, 2X, I1
3	UINF, RINF, R, TWK, HTØTAL, RVW	6E12.0
4	DELTA, DTIL, RZB, RE, PDTIL	5E12.0
5	T(I)	6E12.0
6A	RHØ(I)	6E12.0
6B	RM(I)	6E12.0
7	DEPS	E12.0
8	ETA(I)	6E12.0
9	NDEBUG, IRS, IAB	3I5
10	CWALL(J)	5E15.8

TABLE D.2

VARIABLE DEFINITIONS FOR VISRAD 3

Variable	Description
TITLE	Title for identification of the problem.
KEEP	Indicator to determine if the temperature profile from the previous case is to be kept as a guess for the current case. KEEP = 0 Temperature not kept KEEP = 1 Temperature kept
NETA	The number of points to be used in the shock layer profile. If NETA = 0, a set of 51 equally spaced points will be used. If NETA > 0 card 8 must be read.
IRAD	A variable used to specify the type of solution. IRAD = 1 Convective solution only = 2 Uncoupled radiation solution = 3 Coupled radiation solution
ITYPE	A variable used to specify the type of radiation model to be used. ITYPE = 0 Line and continuum radiation model = 1 Emission radiation model
MAXM	Maximum number of iterations allowed in the internal momentum loop. If MAXM = 0, it is internally set = 15.
MAXE	Maximum number of iterations allowed in the energy equation and in the overall momentum-energy loop. If MAXE = 0, it is internally set = 15.
MAXD	Maximum number of iterations allowed in the external momentum loop. If MAXD = 0, it is internally set = 15.
LT	Indicator to determine if a temperature guess and if ρ & $\rho\mu$ guesses are to be read in. LT = 0 Cards 5 and 6 are not read. = 1 Card 5 but not card 6 is read. = 2 Cards 5 and 6 are read.

TABLE D.2 (Cont.)

IPHI	Indicator to determine if the shock curvature is to be input. IPHI = 0 $d\epsilon/d\xi = 0$ is internally set. = 1 Card 7 is required for input.
FPRCT	Convergence tolerance for each point in the f' profile. If FPRCT = 0.0 it is internally set = .005.
TPRCT	Convergence tolerance for each point in the T profile. If TPRCT = 0.0 it is internally set = .005.
IDEBUG	A switch to allow intermediate printout to be obtained at each iteration IDEBUG = 0 No print. = 1 Print is given.
UNIF	The freestream flight velocity (U_∞) in feet/sec.
RINF	The freestream density (ρ_∞) in slugs/ft^3.
R	Principal body radius in feet.
TWK	Wall temperature in degrees Kelvin.
HTOTAL	Total freestream enthalpy in ft^2/sec^2. If HTOTAL = 0.0, it is set to $U_\infty{}^2/2$. (Freestream static enthalpy is assumed negligible).
RVW	Mass injection rate $(\rho v)_w/(\rho U)_\infty$.
DELTA	An initial guess for the shock standoff distance δ/R. If DELTA = 0.0, a guess is supplied by program.
DTIL	A guess for the transformed standoff distance $\tilde{\delta}/R$. The program will also supply this value if DTIL = 0.0
RZB	The density ratio across the shock $\bar{\rho} = \rho_\infty/\rho_\delta$. If RZB is input as 0.0, the code will determine a value.
RE	The Reynolds number for the problem, $Re_s = U_\infty R\rho_\delta/\mu_\delta$. This quantity is determined by the program if RE is input as 0.0.

TABLE D.2 (Cont.)

PDTIL	Convergence tolerance placed on $\tilde{\delta}$ for total solution convergence. If PDTIL = 0.0, it is internally set = .001.
T(I),I=1,NETA	An initial guess for the dimensionless shock layer temperature profile (T/T_δ). If LT>0, this profile is supplied by the user.
RHØ(I),I=1,NETA	An initial guess for the dimensionless shock layer density profile (ρ/ρ_δ). If LT = 2, this profile is supplied by the user.
RM(I),I=1,NETA	An initial guess for the dimensionless shock layer $\rho\mu$ profile $(\rho\mu/\rho_\delta\mu_\delta)$. If LT = 2, this profile is supplied by the user.
DEPS	The stagnation line shock curvature $(d\epsilon/d\xi)$. If IPHI = 0 then $d\epsilon/d\xi = 0.0$ is internally set. If IPHI = 1, card 7 is read and $d\epsilon/d\xi$ is supplied by the user.
ETA(I),I=1,NETA	The grid shock layer points at which the solution profiles are to be computed. If NETA = 0, $\Delta\eta$ is set to 0.02 and ETA(I) is computed by the program. (ETA(1)=0.0→wall, ETA(NETA)=1.0→shock).
NDEBUG	Debug option to output thermodynamic curve-fit equations. NDEBUG = 0 No output. = 1 Output given.
IRS	Indicator to determine if the wall species composition is to be input on Card 10. IRS = 0 Card 10 not read and wall mass fractions are set equal to those for a nylon-phenolic ablator. IRS > 1 Card 10 is read. Wall mass factions are provided by the user.
IAB	Indicator to determine at what iteration (IEM) the ablation products are included in the computation. IAB = 0 Ablation products are introduced at IEM = 5. IAB > 0 Ablation products are introduced at IEM = IAB - 1.

TABLE D.2 (Cont.)

CWALL(J),J=1,NSP	Wall mass fractions. NSP = 20				
	J =	$1 \rightarrow O_2$	$6 \rightarrow N^+$	$11 \rightarrow CO$	$16 \rightarrow C_3H$
		$2 \rightarrow N_2$	$7 \rightarrow E^-$	$12 \rightarrow C_3$	$17 \rightarrow C_4H$
		$3 \rightarrow O$	$8 \rightarrow C$	$13 \rightarrow CN$	$18 \rightarrow HCN$
		$4 \rightarrow N$	$9 \rightarrow H$	$14 \rightarrow C_2H$	$19 \rightarrow C_2$
		$5 \rightarrow O^+$	$10 \rightarrow H_2$	$15 \rightarrow C_2H_2$	$20 \rightarrow C^+$

Some caution should be exercised when preparing an input for this program. The present program considers 5 elements, including electrons, and twenty species listed under CWALL(J). The set of species was selected for an air atmosphere and an phenolic-nylon ablator. If another ablator is selected for study and this set of species is appropriate, no alteration of the program is required. All that is required is a card input of wall mass fractions of the ablator selected on Card 10. If extensive study of a different ablator using this program is anticipated, the user may find it convenient to change the wall composition stated in BLØCK DATA under CWALL rather than reading in the data for each run. If required, a change to another set of species for thermodynamic calculations can be made with comparitively little difficulty. This may be achieved by changing the thermodynamic curve-fit constants in BLØCK DATA. The thermodynamic curve-fit equations were listed in Table 3.2 and the correspondence between the coefficients in the table and those in the program is

For

$1000 < T < 6000$				$6000 < T^{o}K$
AI	=	A_1	=	AII
BI	=	A_2	=	BII
CI	=	A_3	=	CII
DI	=	A_4	=	DII
EI	=	A_5	=	EII
FI	=	A_6	=	FII
GI	=	A_7	=	GII

where the coefficients are dimensioned to include a value for each species. The species ordering is given in the SP array with corresponding ordering in SMW (i.e. species molecular weight) array in BLØCK DATA. Curve-fit constants in the proper format for over one-hundred species are available in Ref. D.3. If a different chemical system is chosen for study a check should be made to determine if the species added are radiatively important. This may be achieved using the method suggested in Chapter 3.

An accurate initial guess appears to be necessary for some flight conditions and body radii to avoid convergence difficulties. The most sensitive profile appears to be the shock layer temperature. A library of starting values for the temperature and η profiles should be developed. The VISRAD 3 program provides punched output of these three profiles along with the eta, η, step-size profile. The punched output is in the format for input stated for card type 5, 6A, 6B and 8. This not only provides the user with a means of collecting guesses but also provides the program with a restart capability.

An additional input hint which has proven useful is to run using the emission model first and use this output as input for a run with the detailed radiation model. It has been found that coupled solutions using the emission model are not as sensitive to the input guess as solutions using the detailed radiation model. This method or the start up procedure discussed in the previous section is to be used if a library of guesses has not been developed.

A similar technique has proven useful in running entire trajectories (usually without mass injection). By inputing KEEP = 1, the program will use the solution at the Nth trajectory point as an initial guess for the N+1st trajectory point solution. In the early portion of a typical trajectory the radiative coupling is weak and hence the solution is not as sensitive to the initial guess. Since radiative coupling varies smoothly over the trajectory, the solution at the Nth point provides a reasonable guess for the solution at the N+1st point.

Two changes in the computer program are recommended if extensive use of the program is anticipated. First, substitute a calculation of the total heat capacity of ablation products for that of air which is presently used. This calculation should be made in subroutine PROPRT where the frozen part of the heat capacity for the ablation products is presently computed. The calculation for the reacting part may be computed using the method of Ref. D.2. Secondly, additional logic should be built into subroutine STPSZE which internally adjusts the η step-size. Some numerical difficulties are encountered if the step size is increased to $\Delta\eta = .04$ on the shock side of the stagnation point for $(\rho v)_w > .10$ even though the temperature gradient is small. This subroutine should be modified to provide a smaller step size in this region.

OUTPUT DESCRIPTION

This section presents a description of the program output format and definitions of the output symbols. The reader may find it instructive to refer to the listing of the sample problem presented in the next section while reading this section.

The first page of output is a print of the input data. This is provided for a check of the input and an identification of the problem. All quantities on this page are defined in the INPUT GUIDE section. The second page also contains problem specification data which is self explanatory. Following the guessed nondimensional stand-off distance (DELTA) and transformed stand-off distance (DTIL), a listing of the dimensional stand-off distance computed at each iteration is given if the detailed radiation model is used.

Species number densities for those species used in the radiation calculation during the final iteration are printed on the third page. The fourth page provides an output of radiative fluxes computed during the final iteration. The continuum contribution and line contribution to the spectral flux is printed for three ETA points (ETA = 0.0 = wall, ETA = stagnation point, ETA = 1.0 = shock) as a function of frequency intervals and frequency centers respectively. The columns of fluxes in watts/cm^2 denoted by QPLUS and QMINUS designates fluxes toward the surface and away from the surface respectively.

The fifth page begins with a cheerful message noting the solution converged. Following this message is a printout of the shock stand-off distance parameters (DELTA,DTIL); the convective (QC), radiative (QR), and total heating rate; and the radiative heat transfer coefficient (CHR). To the left of the heating rate data the density ratio across the shock (RB) and the mass injection rate (RVW) are stated. Following the heating rate data is a print of the numerical

of the solution profiles as a function of the shock layer coordinates ETA and (Y/D). The solution profiles printed are:

F' = velocity function

RV = $\rho v/\rho_\infty U_\infty$ (nondimensional mass flux per unit area)

T/TD = T/T_δ (nondimensional temperature)

E = $\mathbb{E}$ (radiative flux divergence)

V = v/U_∞ (nondimensional normal velocity)

V(fT/SEC) = dimensional normal velocity

G = nondimensional total enthalpy

H(STATIC) = nondimensional static enthalpy

The shock layer thermodynamic and transport properties are output beginning on the following page. These properties are then followed by a print of the species mass fractions output as a function of ETA. In addition to the species on the last page of output, the mixture heat capacity (CP) and average molecular weight (AMW) are also printed.

The above description is for a standard output. If, however, the intermediate print option is used (i.e. IDEBUG > 0) additional information is printed related to the momentum and energy equation convergence as well as the information just described given at each energy-momentum iteration. The additional information is clearly labled and thus no difficulties should be encountered in its interpretation.

SAMPLE PROBLEM AND PROGRAM LISTING

The following example is presented to illustrate the basic input for the VISRAD 3 program and to show a typical output listing. The

conditions defining the problem are:

U_∞ = 50000. ft/sec

$\rho_\infty = 2.69 \times 10^{-7}$ slug/ft^3

R = 9 ft

$(\rho v)_w$ = .20

$(d\epsilon/d\xi)_{\xi=0}$ = 0.0 (internally set)

$T_w = 3450^\circ K$

$$\left.\begin{aligned}\tilde{C}_{iw} = &.7303 \text{ carbon}\\ &.0729 \text{ hydrogen}\\ &.0496 \text{ nitrogen}\\ &.1472 \text{ oxygen}\end{aligned}\right\} \text{(internally set)}$$

Coupled radiative heating rates are to be obtained from the stagnation line solution using the line and continuum radiation model. The solution is started using a set of T/T_δ, ρ/ρ_δ, $(\rho\mu)/(\rho\mu)_\delta$ and η profiles and thus LT = 2 on card type 2. Card type 4 is a blank card. A listing of the necessary card input data is shown on the following page.

```
VISRAD 3 SAMPLE CASE
 57    3                                     2
50000. 2.69    E-7               9.          3450.                  .20

0.24786E 00 0.25036E 00 0.25306E 00 0.25559E 00 0.25992E 00 0.26483E 00
0.27154E 00 0.28086E 00 0.29548E 00 0.30978E 00 0.33820E 00 0.35857E 00
0.36503E 00 0.37614E 00 0.38532E 00 0.39535E 00 0.40085E 00 0.41197E 00
0.42359E 00 0.43582E 00 0.44969E 00 0.46472E 00 0.47015E 00 0.47676E 00
0.49246E 00 0.52385E 00 0.58351E 00 0.64499E 00 0.67189E 00 0.68314E 00
0.69374E 00 0.70437E 00 0.71537E 00 0.72725E 00 0.75719E 00 0.80915E 00
0.78083E 00 0.78021E 00 0.78341E 00 0.78726E 00 0.80003E 00 0.81047E 00
0.86701E 00 0.85956E 00 0.86316E 00 0.87469E 00 0.88276E 00 0.89433E 00
0.90202E 00 0.91507E 00 0.92218E 00 0.93630E 00 0.94340E 00 0.95738E 00
0.96643E 00 0.98448E 00 0.10000E 01
0.60406E 01 0.58809E 01 0.57110E 01 0.55561E 01 0.53037E 01 0.50256E 01
0.46704E 01 0.42205E 01 0.36101E 01 0.31363E 01 0.25429E 01 0.23048E 01
0.22449E 01 0.21571E 01 0.20916E 01 0.20260E 01 0.19921E 01 0.19272E 01
0.18633E 01 0.17974E 01 0.17277E 01 0.16548E 01 0.16291E 01 0.15984E 01
0.15292E 01 0.14117E 01 0.12427E 01 0.10999E 01 0.10399E 01 0.10162E 01
0.99374E 00 0.98390E 00 0.97386E 00 0.96295E 00 0.94010E 00 0.89397E 00
0.95124E 00 0.95822E 00 0.96050E 00 0.96195E 00 0.96479E 00 0.96433E 00
0.94621E 00 0.97698E 00 0.10403E 01 0.10710E 01 0.11052E 01 0.11776E 01
0.12106E 01 0.12782E 01 0.12531E 01 0.12020E 01 0.11771E 01 0.11296E 01
0.11001E 01 0.10444E 01 0.10000E 01
0.74514E 01 0.73819E 01 0.73096E 01 0.72447E 01 0.71395E 01 0.70306E 01
0.68992E 01 0.67451E 01 0.65517E 01 0.63947E 01 0.61143E 01 0.59138E 01
0.58475E 01 0.57288E 01 0.56254E 01 0.55060E 01 0.54376E 01 0.52930E 01
0.51338E 01 0.49599E 01 0.47604E 01 0.45513E 01 0.44736E 01 0.43968E 01
0.42219E 01 0.39790E 01 0.37481E 01 0.35639E 01 0.34743E 01 0.34339E 01
0.33936E 01 0.33506E 01 0.33031E 01 0.32478E 01 0.30884E 01 0.27359E 01
0.29403E 01 0.29444E 01 0.29229E 01 0.28964E 01 0.28049E 01 0.27256E 01
0.22364E 01 0.23058E 01 0.22724E 01 0.21637E 01 0.20863E 01 0.19740E 01
0.18987E 01 0.17706E 01 0.17010E 01 0.15640E 01 0.14962E 01 0.13652E 01
0.12829E 01 0.11260E 01 0.10000E 01
0.0         0.32500E-01 0.62500E-01 0.86250E-01 0.12000E 00 0.15000E 00
0.18000E 00 0.21000E 00 0.24000E 00 0.26000E 00 0.30000E 00 0.33000E 00
```

0.34000E 00	0.35750E 00	0.37250E 00	0.39000E 00	0.40000E 00	0.42000E 00
0.44000E 00	0.46000E 00	0.48000E 00	0.50000E 00	0.50500E 00	0.51000E 00
0.52000E 00	0.53000E 00	0.53750E 00	0.54500E 00	0.54875E 00	0.55062E 00
0.55250E 00	0.55437E 00	0.55625E 00	0.55812E 00	0.56406E 00	0.57000E 00
0.58000E 00	0.58250E 00	0.58500E 00	0.58750E 00	0.59500E 00	0.60000E 00
0.62000E 00	0.63000E 00	0.66000E 00	0.68000E 00	0.70000E 00	0.74000E 00
0.76000E 00	0.80000E 00	0.82000E 00	0.86000E 00	0.88000E 00	0.92000E 00
0.94000E 00	0.98000E 00	0.10000E 01			

1

The output listing for the stated example is listed on the following nine pages. A description of the output format is given in the previous section. Following the output listing of the sample problem a listing of the VISRAD 3 program is given.

Subsequent to the publication of the following it was noted that after card ENER 880 a card stating

```
COE = 2.1 DTIL
```

and card ENER 890 should then read

```
A1 = -COEF*(TARM1 + TARM2 - COE*TARM3)
```

```
VISRAD 3 SAMPLE CASE


INPUT DATA


KEEP    =    0
NETA    =   57
MAXM    =   15
MAXE    =   15
MAXD    =   15
FPRCT   =   4.999999E-03
TPRCT   =   4.999999E-03
LT      =    2
IDEBUG  =    0
IPHI    =    0

UINF    =   5.000000E 04
RINF    =   2.690000E-07
R       =   9.000000E 00
TW      =   3.450000E 03
HTOTAL  =   1.250000E 09
RVW     =   2.000000E-01
PUTIL   =   9.999999E-04

* COUPLED RADIATION CALCULATION *
* CONTINUUM AND LINE CALCULATION *

INITIAL T PROFILE
  0.24786  0.25036  0.25306  0.25559  0.25992  0.26483  0.27154  0.28086  0.29548  0.30978  0.33820  0.35857
  0.36503  0.37614  0.38532  0.39535  0.40085  0.41197  0.42359  0.43582  0.44969  0.46472  0.47015  0.47676
  0.49246  0.52385  0.58351  0.64459  0.67189  0.68314  0.69374  0.70437  0.71537  0.72725  0.75719  0.80915
  0.78083  0.78021  0.78341  0.78726  0.80003  0.81047  0.86701  0.85956  0.86316  0.87469  0.88276  0.89433
  0.90202  0.91507  0.92218  0.93630  0.94340  0.95738  0.96643  0.98448  1.00000

INITIAL RHO PROFILE
  6.04060  5.88090  5.71100  5.55610  5.30370  5.02560  4.67340  4.22050  3.61010  3.13630  2.54290  2.30480
  2.24490  2.15710  2.09160  2.02600  1.99210  1.92720  1.86330  1.79740  1.72770  1.65480  1.62910  1.59840
  1.52920  1.41170  1.24270  1.09990  1.03990  1.01620  0.99374  0.98390  0.97386  0.96295  0.94010  0.89397
  0.95124  0.95822  0.96050  0.96195  0.96479  0.96433  0.94621  0.97698  1.04030  1.07100  1.10520  1.17760
  1.21060  1.27820  1.25310  1.20200  1.17710  1.12960  1.10010  1.04440  1.00000

INITIAL RN  PROFILE
  7.45140  7.38190  7.30960  7.24470  7.13950  7.03060  6.89920  6.74510  6.55170  6.39470  6.11430  5.91380
  5.84750  5.72880  5.62540  5.50600  5.43760  5.29300  5.11380  4.95990  4.76040  4.55130  4.47960  4.39680
  4.22190  3.97500  3.74810  3.56390  3.47430  3.43390  3.31360  3.35060  3.30310  3.24780  3.08840  2.73590
  2.94030  2.94440  2.52290  2.89640  2.80490  2.72560  2.23640  2.30580  2.27240  2.16370  2.08630  1.97400
  1.89870  1.77060  1.70100  1.56400  1.49620  1.36520  1.21290  1.12600  1.00000

DEPS/DX1
   0.0
ABLATION PRODUCTS ARE INTRODUCED AT ITERATION IAB=  0
SPECIES INPUTS
NO. ELEMENTS =     5
```

NO. SPECIES = 20

1 C	2 H	3 N	4 O	5 E
1 O2	2 N2	3 O	4 N	5 O+
6 N+	7 E-	8 C	9 H	10 H2
11 CO	12 C3-G	13 CN	14 C2H	15 C2H2
16 C3H	17 C4H	18 HCN	19 C2	20 C+

NO. SOLIDS = 0

SPECIES NAME	SMW	WALL MASS FRACTION
O2	32.000	0.1000E-09
N2	28.016	0.2385E-01
O	16.000	0.5966E-07
N	14.008	0.1838E-04
O+	16.000	0.1000E-09
N+	14.008	0.1000E-09
E-	0.001	0.1000E-09
C	12.011	0.1573E-02
H	1.008	0.1708E-01
H2	2.016	0.3277E-01
CO	28.011	0.2578E 00
C3-G	36.033	0.1767E-01
CN	26.019	0.3105E-02
C2H	25.030	0.1500E 00
C2H2	26.038	0.8210E-01
C3H	37.041	0.2037E 00
C4H	49.052	0.1589E 00
HCN	27.027	0.4710E-01
C2	24.022	0.4130E-02
C+	12.011	0.1000E-09

DENSITY RATIO	REYNOLDS NO.
0.568472E-01	0.799389E 06

DELTA	DTIL
0.443408E-01	0.288775E 00

DELTA= 1.7695755E 01 CM

DELTA= 1.7831619E 01 CM

DELTA= 1.6564407E 01 CM

DELTA= 1.6704941E 01 CM

DELTA= 1.6942017E 01 CM

NUMBER DENSITIES (PARTICLES/CM3)

ETA	N2	O2	N	O	E-	H	C	C2	H2	CO	C3	C2H
0.0	5.78E 15	2.63E 03	1.93E 13	4.58E 10	9.23E 12	2.53E 17	3.70E 15	4.20E 15	1.08E 17	8.20E 16	1.14E 16	6.55E 16
3.25E-02	5.47E 15	3.17E 03	2.21E 13	5.42E 10	3.55E 13	2.61E 17	4.43E 15	4.89E 15	9.94E 16	7.98E 16	1.23E 16	6.53E 16
6.25E-02	5.16E 15	3.75E 03	2.55E 13	6.47E 10	6.67E 13	2.70E 17	5.36E 15	5.73E 15	9.04E 16	7.75E 16	1.33E 16	6.49E 16
8.62E-02	4.87E 15	4.44E 03	2.90E 13	7.61E 10	8.22E 13	2.77E 17	6.35E 15	6.61E 15	8.26E 16	7.54E 16	1.42E 16	6.42E 16
1.20E-01	4.38E 15	5.02E 03	3.59E 13	9.98E 10	7.12E 13	2.89E 17	8.43E 15	9.35E 15	7.01E 16	7.19E 16	1.59E 16	6.25E 16
1.50E-01	3.88E 15	7.78E 03	4.46E 13	1.33E 11	8.38E 13	2.99E 17	1.13E 16	1.06E 16	5.81E 16	6.83E 16	1.76E 16	5.98E 16
1.80E-01	3.24E 15	1.16E 04	5.89E 13	1.96E 11	1.03E 14	3.09E 17	1.66E 16	1.43E 16	4.43E 16	6.36E 16	1.97E 16	5.40E 16
2.10E-01	2.48E 15	1.95E 04	8.17E 13	3.30E 11	1.14E 14	3.16E 17	2.67E 16	2.03E 16	2.97E 16	5.76E 16	2.14E 16	4.59E 16
2.40E-01	1.65E 15	4.96E 04	1.41E 14	7.52E 11	1.20E 14	3.14E 17	5.07E 16	2.98E 16	1.49E 16	4.91E 16	1.93E 16	2.90E 16
2.60E-01	1.31E 15	1.26E 05	2.17E 14	1.60E 12	1.00E 14	3.03E 17	7.60E 16	3.31E 16	8.45E 15	4.35E 16	1.38E 16	1.60E 16
3.00E-01	1.17E 15	1.14E 06	5.59E 14	6.07E 12	8.18E 13	2.70E 17	1.22E 17	2.43E 16	2.70E 15	3.56E 16	3.47E 15	3.54E 15
3.30E-01	1.32E 15	6.81E 06	1.16E 15	2.83E 13	7.93E 13	2.49E 17	1.40E 17	1.37E 16	1.23E 15	3.21E 16	7.05E 14	8.49E 14
3.40E-01	1.38E 15	1.22E 07	1.43E 15	4.16E 13	8.03E 13	2.43E 17	1.43E 17	1.10E 16	9.57E 14	3.12E 16	4.23E 14	4.84E 14
3.57E-01	1.44E 15	2.63E 07	1.90E 15	7.02E 13	8.34E 13	2.34E 17	1.45E 17	7.81E 15	6.78E 14	2.99E 16	1.81E 14	2.26E 14
3.72E-01	1.47E 15	6.25E 07	2.57E 15	1.27E 14	9.29E 13	2.27E 17	1.46E 17	5.36E 15	4.02E 14	2.89E 16	8.07E 13	1.09E 14
3.90E-01	1.37E 15	2.22E 08	3.48E 15	2.79E 14	1.15E 14	2.20E 17	1.45E 17	3.91E 15	3.65E 14	2.78E 16	4.42E 13	6.30E 13
4.00E-01	1.32E 15	3.59E 08	3.93E 15	3.78E 14	1.27E 14	2.16E 17	1.44E 17	3.17E 15	3.04E 14	2.72E 16	2.40E 13	4.08E 13
4.20E-01	1.13E 15	9.94E 08	4.92E 15	7.30E 14	1.64E 14	2.08E 17	1.42E 17	2.17E 15	2.20E 14	2.59E 16	1.21E 13	2.04E 13
4.40E-01	8.97E 14	2.60E 09	5.85E 15	1.35E 15	2.16E 14	2.01E 17	1.40E 17	1.47E 15	1.59E 14	2.44E 16	4.52E 12	9.64E 12
4.60E-01	6.60E 14	6.39E 09	6.64E 15	2.42E 15	2.88E 14	1.94E 17	1.37E 17	1.01E 15	1.15E 14	2.24E 16	2.36E 12	4.76E 12
4.80E-01	4.79E 14	1.47E 10	7.40E 15	3.71E 15	3.47E 14	1.86E 17	1.35E 17	6.59E 14	8.03E 13	2.01E 16	1.50E 12	2.13E 12
5.00E-01	2.80E 14	3.26E 10	8.01E 15	6.26E 15	4.86E 14	1.78E 17	1.32E 17	4.42E 14	5.65E 13	1.65E 16	4.17E 11	9.81E 11
5.05E-01	2.14E 14	4.10E 10	8.03E 15	7.44E 15	5.53E 14	1.75E 17	1.31E 17	3.70E 14	4.84E 13	1.49E 16	2.70E 11	6.74E 11
5.10E-01	1.60E 14	5.29E 10	7.97E 15	9.11E 15	6.64E 14	1.71E 17	1.30E 17	3.06E 14	4.08E 13	1.27E 16	1.66E 11	4.80E 11
5.12E-01	1.29E 14	5.99E 10	7.52E 15	1.01E 16	7.30E 14	1.69E 17	1.29E 17	2.67E 14	3.62E 13	1.14E 16	1.36E 11	3.64E 11
5.15E-01	1.01E 14	6.74E 10	7.40E 15	1.13E 16	8.36E 14	1.65E 17	1.28E 17	2.29E 14	3.16E 13	9.77E 15	9.79E 10	2.71E 11
5.20E-01	5.46E 13	7.77E 10	7.63E 15	1.28E 16	1.13E 15	1.58E 17	1.25E 17	1.58E 14	2.28E 13	6.34E 15	4.19E 10	1.29E 11
5.25E-01	2.23E 13	6.95E 10	7.26E 15	1.61E 16	1.92E 15	1.48E 17	1.20E 17	6.97E 13	1.42E 13	2.82E 16	1.17E 10	4.43E 10
5.30E-01	7.00E 12	4.71E 10	6.76E 15	1.67E 16	3.19E 15	1.37E 17	1.12E 17	4.24E 13	7.95E 12	6.53E 14	2.63E 09	1.13E 10
5.34E-01	2.46E 12	2.83E 10	6.31E 15	1.60E 16	5.07E 15	1.28E 17	1.02E 17	2.07E 13	4.71E 12	2.75E 14	6.18E 08	3.22E 09
5.37E-01	1.06E 12	1.78E 10	5.86E 15	1.50E 16	8.10E 15	1.19E 17	9.21E 16	1.12E 13	3.03E 12	1.09E 14	1.82E 08	1.14E 09
5.45E-01	5.48E 11	1.28E 10	5.73E 15	1.40E 16	1.13E 16	1.17E 17	8.72E 16	6.64E 12	2.22E 12	5.14E 13	6.70E 07	4.89E 08
5.49E-01	5.07E 11	1.23E 10	5.77E 15	1.49E 16	1.21E 16	1.16E 17	8.70E 16	6.46E 12	2.15E 12	4.70E 13	5.80E 07	4.37E 08
5.52E-01	3.16E 11	9.66E 09	5.63E 15	1.46E 16	1.51E 16	1.11E 17	8.21E 16	4.47E 12	1.72E 12	2.72E 13	2.57E 07	2.30E 08
5.56E-01	2.49E 11	8.51E 09	5.59E 15	1.45E 16	1.72E 16	1.11E 17	7.97E 16	3.66E 12	1.53E 12	2.60E 13	1.86E 07	1.69E 08
5.58E-01	2.24E 11	8.07E 09	5.57E 15	1.45E 16	1.81E 16	1.15E 17	7.87E 16	3.35E 12	1.46E 12	1.83E 13	1.55E 07	1.46E 08
5.64E-01	1.74E 11	7.15E 09	5.57E 15	1.45E 16	2.03E 16	1.15E 17	7.67E 16	2.72E 12	1.31E 12	1.35E 13	9.72E 06	1.01E 08
5.70E-01	1.50E 11	6.62E 09	5.58E 15	1.45E 16	2.25E 16	1.16E 17	7.51E 16	2.38E 12	1.23E 12	1.15E 13	7.81E 06	8.30E 07
5.80E-01	1.91E 11	7.68E 09	5.87E 15	1.53E 16	2.11E 16	1.21E 17	8.11E 16	2.96E 12	1.41E 12	1.51E 13	1.13E 07	1.14E 08
5.82E-01	2.02E 11	7.89E 09	5.93E 15	1.54E 16	2.11E 16	1.22E 17	8.21E 16	3.09E 12	1.44E 12	1.60E 13	1.24E 07	1.23E 08
5.85E-01	9.98E 13	9.45E 10	8.95E 16	2.24E 16	5.29E 15	1.64E-02	1.41E-03	7.07E-04	8.43E-03	6.07E-04	4.72E-04	6.79E-04
5.87E-01	8.87E 13	7.34E 10	8.90E 16	2.23E 16	5.75E 15	1.64E-02	1.41E-03	7.06E-04	8.41E-03	6.06E-04	4.71E-04	6.78E-04
5.95E-01	5.02E 13	5.47E 10	8.45E 16	2.13E 16	8.41E 15	1.65E-02	1.38E-03	6.91E-04	8.23E-03	5.93E-04	4.61E-04	6.63E-04
6.00E-01	3.77E 13	4.75E 10	8.27E 16	2.07E 16	1.02E 16	1.63E-02	1.37E-03	6.85E-04	8.17E-03	5.88E-04	4.57E-04	6.58E-04
6.20E-01	2.03E 13	5.45E 10	7.85E 16	1.56E 16	1.60E 16	1.64E-02	1.38E-03	6.88E-04	8.20E-03	5.90E-04	4.59E-04	6.60E-04
6.30E-01	1.77E 13	4.49E 10	7.81E 16	1.95E 16	1.01E 16	1.66E-02	1.39E-03	6.97E-04	8.31E-03	5.98E-04	4.65E-04	6.69E-04
6.60E-01	1.61E 13	3.31E 10	8.13E 16	2.04E 16	2.15E 16	1.77E-02	1.40E-03	7.42E-04	8.85E-03	6.37E-04	4.95E-04	7.12E-04
6.80E-01	1.37E 13	4.17E 10	8.14E 16	2.04E 16	2.53E 16	1.83E-02	1.53E-03	7.66E-04	9.13E-03	6.57E-04	5.11E-04	7.35E-04
7.00E-01	1.16E 13	3.12E 10	8.08E 16	2.02E 16	2.98E 16	1.89E-02	1.50E-03	7.88E-04	9.39E-03	6.76E-04	5.25E-04	7.56E-04
7.40E-01	9.42E 12	3.73E 10	8.08E 16	2.02E 16	3.80E 16	2.03E-02	1.60E-03	8.38E-04	9.98E-03	7.18E-04	5.58E-04	8.04E-04
7.60E-01	8.31E 12	3.64E 10	7.68E 16	1.92E 16	3.98E 16	1.95E-02	1.64E-03	8.18E-04	9.75E-03	7.01E-04	5.45E-04	7.85E-04
8.00E-01	6.82E 12	2.34E 10	7.06E 16	1.77E 16	4.24E 16	1.81E-02	1.57E-03	7.87E-04	9.38E-03	6.75E-04	5.25E-04	7.55E-04
8.20E-01	6.16E 12	2.29E 10	6.75E 16	1.69E 16	4.37E 16	1.83E-02	1.54E-03	7.71E-04	9.19E-03	6.61E-04	5.14E-04	7.40E-04
8.60E-01	5.16E 12	1.10E 10	6.10E 16	1.55E 16	4.61E 16	1.77E-02	1.49E-03	7.43E-04	8.85E-03	6.37E-04	4.95E-04	7.13E-04
8.80E-01	4.69E 12	1.08E 10	5.89E 16	1.47E 16	4.73E 16	1.74E-02	1.46E-03	7.20E-04	8.68E-03	6.24E-04	4.85E-04	6.99E-04
9.20E-01	3.85E 12	2.77E 10	5.30E 16	1.33E 16	4.98E 16	1.66E-02	1.40E-03	6.99E-04	8.32E-03	5.99E-04	4.66E-04	6.71E-04
9.40E-01	3.47E 12	2.70E 10	4.90E 16	1.25E 16	5.11E 16	1.63E-02	1.36E-03	6.82E-04	8.13E-03	5.85E-04	4.55E-04	6.55E-04
9.60E-01	2.54E 12	[illegible]	4.12E 16	1.03E 16	5.45E 16	1.52E-02	1.26E-03	6.39E-04	7.61E-03	5.48E-04	4.26E-04	6.13E-04
1.00E 00	2.11E 12	1.52E 10	3.66E 16	9.15E 15	5.63E 16	1.46E-02	1.23E-03	6.14E-04	7.12E-03	5.27E-04	4.09E-04	5.89E-04

CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX

		ETA = 0.0		ETA = 0.595		ETA = 1.000	
I	HNU	OMINUS	OPLUS	OMINUS	OPLUS	OMINUS	OPLUS
1	5.000	0.0	3.951E 02	1.375E 01	3.815E 02	3.953E 02	0.0
2	6.000	0.0	1.092E 01	4.086E 00	1.036E 01	2.245E 01	0.0
3	7.000	0.0	9.851E 00	2.112E 00	1.101E 01	1.312E 01	0.0
4	8.000	0.0	1.909E 00	1.071E 01	6.538E 00	1.724E 01	0.0
5	9.000	0.0	7.735E-04	1.355E 01	3.966E 00	1.751E 01	0.0
6	10.000	0.0	9.564E-01	4.883E 00	2.283E 00	7.162E 00	0.0
7	10.000	0.0	9.828E 00	2.303E 01	1.632E-01	2.319E 01	0.0
8	11.100	0.0	3.487E 01	5.450E 00	1.076E 02	1.275E 02	0.0
9	12.000	0.0	1.253E-04	2.573E 01	1.672E 02	2.098E 02	0.0
10	13.400	0.0	2.756E-08	1.743E 01	2.700E 02	5.686E 02	0.0
11	14.300	0.0	1.181E-12	4.409E 00	6.326E 01	2.019E 02	0.0
12	20.000	0.0	5.261E-06	3.491E 00	2.635E 01	3.332E 02	0.0
TOTAL FLUX		0.0	4.634E 02	1.326E 02	1.058E 03	1.937E 03	0.0

LINE CONTRIBUTION TO THE SPECTRAL FLUX

		ETA = 0.0		ETA = 0.595		ETA = 1.000	
I	HNU	OMINUS	OPLUS	OMINUS	OPLUS	OMINUS	OPLUS
1	1.300	0.0	2.830E 02	3.472E 01	2.495E 02	3.038E 02	0.0
2	2.700	0.0	8.624E 01	9.520E 00	7.610E 01	8.627E 01	0.0
3	5.750	0.0	4.698E 00	1.684E 01	-5.691E-11	1.682E 01	0.0
4	7.570	0.0	1.771E 01	6.813E 01	1.552E 02	2.959E 02	0.0
5	9.100	0.0	1.822E 01	8.168E 01	1.093E 02	2.520E 02	0.0
6	10.400	0.0	7.121E 01	2.412E 01	3.642E 02	6.614E 02	0.0
7	11.400	0.0	-4.872E-05	5.518E 00	1.512E 02	4.391E 02	0.0
8	12.700	0.0	-1.764E-07	1.256E 00	-3.236E 01	1.348E 02	0.0
9	13.900	0.0	-3.535E-15	3.902E-01	-2.228E 01	7.489E 01	0.0
TOTAL FLUX		0.0	4.811E 02	2.426E 02	1.051E 03	2.265E 03	0.0

SOLUTION CONVERGED IN 5 ITERATIONS

XI = 0.0	DELTA = 6.162129E-02		DTIL = 1.060886E-01			
EPS = 0.0	QC = -0.108382E 01 (WATTS/CM**2)	=	-0.953759E 00 (BTU/FT**2 - SEC)			
RD = 0.0568	QR = -0.544554E 03 (WATTS/CM**2)	=	-0.331208E 03 (BTU/FT**2 - SEC)			
RVW= 0.2000	QKR = -0.517044E 03	CFR = -0.274963E 03			CHR = -0.384781E-01	
	QRT = -0.266282E 04	CT = -0.317986E 04				

TOTAL HEATING = -0.945638E 03 (WATTS/CM**2) = -0.832161E 03 (BTU/FT**2 - SEC)

HEATING DISTRIBUTION QC/QCZ = 0.100000E 01 QR/QRZ = 0.100000E 01 QT/QTZ = 0.100000E 01

	ETA	Y/CZ	F'	RV	T/TO	E(WATTS/CM3)	V	V (FT/SEC)	G	H (STATIC)
WALL	0.0	0.0	0.0	1.137E-02	2.479E-01	-3.321E 01	1.882E-03	9.411E 01	6.523E-02	6.523E-02
	0.032	9.376E-03	5.466E-03	1.137E-02	2.502E-01	-3.709E 01	1.935E-03	9.676E 01	6.700E-02	6.700E-02
	0.063	1.826E-02	1.066E-02	1.132E-02	2.526E-01	-4.066E 01	1.984E-03	9.922E 01	6.886E-02	6.888E-02
	0.086	2.547E-02	1.490E-02	1.126E-02	2.549E-01	-4.397E 01	2.028E-03	1.014E 02	7.069E-02	7.069E-02
	0.120	3.606E-02	2.116E-02	1.113E-02	2.586E-01	-4.872E 01	2.101E-03	1.051E 02	7.370E-02	7.370E-02
	0.150	4.588E-02	2.700E-02	1.097E-02	2.628E-01	-5.341E 01	2.182E-03	1.091E 02	7.725E-02	7.725E-02
	0.180	5.623E-02	3.326E-02	1.078E-02	2.681E-01	-5.809E 01	2.301E-03	1.151E 02	8.199E-02	8.199E-02
	0.210	6.731E-02	4.006E-02	1.055E-02	2.754E-01	-6.105E 01	2.485E-03	1.243E 02	8.926E-02	8.926E-02
	0.240	7.551E-02	4.803E-02	1.027E-02	2.855E-01	-6.569E 01	2.839E-03	1.420E 02	1.001E-01	1.000E-01
	0.260	8.855E-02	5.432E-02	1.005E-02	2.952E-01	-6.687E 01	3.137E-03	1.568E 02	1.115E-01	1.115E-01
	0.300	1.100E-01	6.917E-02	9.526E-03	3.195E-01	-6.940E 01	3.620E-03	1.814E 02	1.298E-01	1.358E-01
	0.330	1.291E-01	8.251E-02	9.043E-03	3.305E-01	-7.482E 01	3.823E-03	1.912E 02	1.561E-01	1.561E-01
	0.340	1.360E-01	8.718E-02	8.603E-03	3.444E-01	-7.662E 01	3.852E-03	1.926E 02	1.599E-01	1.559E-01
	0.357	1.485E-01	9.566E-02	8.524E-03	3.548E-01	-8.218E 01	3.857E-03	1.929E 02	1.652E-01	1.651E-01
	0.372	1.598E-01	1.033E-01	8.207E-03	3.634E-01	-8.694E 01	3.838E-03	1.919E 02	1.687E-01	1.687E-01
	0.390	1.731E-01	1.125E-01	7.807E-03	3.732E-01	-9.401E 01	3.774E-03	1.887E 02	1.721E-01	1.720E-01
	0.400	1.813E-01	1.179E-01	7.562E-03	3.787E-01	-9.805E 01	3.723E-03	1.861E 02	1.738E-01	1.731E-01
	0.420	1.977E-01	1.292E-01	7.038E-03	3.859E-01	-1.077E 02	3.509E-03	1.794E 02	1.769E-01	1.769E-01
	0.440	2.147E-01	1.411E-01	6.465E-03	4.014E-01	-1.173E 02	3.415E-03	1.707E 02	1.800E-01	1.799E-01
	0.460	2.324E-01	1.536E-01	5.840E-03	4.147E-01	-1.288E 02	3.198E-03	1.559E 02	1.836E-01	1.836E-01
	0.480	2.508E-01	1.670E-01	5.160E-03	4.291E-01	-1.402E 02	2.946E-03	1.473E 02	1.878E-01	1.878E-01
	0.500	2.700E-01	1.816E-01	4.420E-03	4.444E-01	-1.555E 02	2.636E-03	1.318E 02	1.930E-01	1.930E-01
	0.505	2.749E-01	1.859E-01	4.225E-03	4.500E-01	-1.593E 02	2.567E-03	1.284E 02	1.949E-01	1.949E-01
	0.510	2.800E-01	1.905E-01	4.025E-03	4.559E-01	-1.620E 02	2.505E-03	1.252E 02	1.971E-01	1.971E-01
	0.512	2.825E-01	1.929E-01	3.924E-03	4.610E-01	-1.633E 02	2.479E-03	1.239E 02	1.990E-01	1.990E-01
	0.515	2.851E-01	1.955E-01	3.821E-03	4.671E-01	-1.654E 02	2.458E-03	1.226E 02	2.016E-01	2.010E-01
	0.520	2.905E-01	2.011E-01	3.610E-03	4.836E-01	-1.695E 02	2.432E-03	1.218E 02	2.088E-01	2.088E-01
	0.525	2.962E-01	2.074E-01	3.394E-03	5.081E-01	-1.918E 02	2.434E-03	1.217E 02	2.188E-01	2.188E-01
	0.530	3.023E-01	2.145E-01	3.170E-03	5.422E-01	-2.142E 02	2.456E-03	1.220E 02	2.294E-01	2.294E-01
	0.534	3.072E-01	2.203E-01	2.997E-03	5.766E-01	-1.766E 02	2.494E-03	1.247E 02	2.384E-01	2.384E-01
	0.537	3.125E-01	2.264E-01	2.819E-03	6.111E-01	-1.390E 02	2.523E-03	1.261E 02	2.479E-01	2.479E-01
	0.545	3.238E-01	2.390E-01	2.449E-03	6.388E-01	-1.913E 02	2.232E-03	1.116E 02	2.567E-01	2.567E-01
	0.549	3.296E-01	2.452E-01	2.256E-03	6.430E-01	-2.174E 02	2.044E-03	1.022E 02	2.583E-01	2.583E-01
	0.552	3.354E-01	2.515E-01	2.059E-03	6.639E-01	-9.605E 01	1.901E-03	9.506E 01	2.663E-01	2.663E-01
	0.556	3.413E-01	2.578E-01	1.856E-03	6.755E-01	2.529E 01	1.723E-03	8.813E 01	2.711E-01	2.711E-01
	0.558	3.443E-01	2.609E-01	1.753E-03	6.805E-01	4.043E 01	1.627E-03	8.145E 01	2.735E-01	2.738E-01

0.564	3.537E-01	2.706E-01	1.418E-03	6.922E-01	9.850E 01	1.315E-03	6.575E 01	2.790E-01	2.790E-01
0.570	3.631E-01	2.800E-01	1.072E-03	7.011E-01	-2.565E 02	9.874E-04	4.937E 01	2.834E-01	2.834E-01
0.580	3.789E-01	2.949E-01	4.618E-04	7.329E-01	-3.372E 02	4.062E-04	2.031E 01	3.008E-01	3.008E-01
0.582	3.829E-01	2.985E-01	3.044E-04	7.400E-01	-4.839E 02	2.653E-04	1.326E 01	3.055E-01	3.055E-01
0.585	3.869E-01	3.022E-01	1.451E-04	7.470E-01	-1.307E 02	1.260E-04	6.301E 00	3.101E-01	3.101E-01
0.587	3.909E-01	3.058E-01	-1.612E-05	7.550E-01	-1.244E 02	-1.402E-05	-7.009E-01	4.692E-01	4.692E-01
0.595	4.031E-01	3.171E-01	-5.117E-04	7.816E-01	-1.055E 02	-4.540E-04	-2.274E 01	4.994E-01	4.994E-01
0.600	4.113E-01	3.248E-01	-8.522E-04	7.957E-01	-7.633E 01	-7.638E-04	-3.819E 01	5.178E-01	5.178E-01
0.620	4.438E-01	3.560E-01	-2.297E-03	8.280E-01	4.048E 01	-2.051E-03	-1.025E 02	5.671E-01	5.671E-01
0.630	4.599E-01	3.713E-01	-3.068E-03	8.385E-01	3.645E 01	-2.703E-03	-1.351E 02	5.856E-01	5.856E-01
0.660	5.065E-01	4.178E-01	-5.579E-03	8.528E-01	2.437E 01	-4.616E-03	-2.308E 02	6.125E-01	6.124E-01
0.680	5.362E-01	4.513E-01	-7.423E-03	8.603E-01	9.620E 01	-5.952E-03	-2.976E 02	6.277E-01	6.276E-01
0.700	5.649E-01	4.855E-01	-9.410E-03	8.708E-01	1.610E 02	-7.335E-03	-3.668E 02	6.498E-01	6.497E-01
0.740	6.197E-01	5.556E-01	-1.383E-02	8.924E-01	2.922E 02	-1.014E-02	-5.070E 02	6.990E-01	6.989E-01
0.760	6.460E-01	5.911E-01	-1.626E-02	9.015E-01	3.542E 02	-1.221E-02	-6.105E 02	7.213E-01	7.212E-01
0.800	6.989E-01	6.602E-01	-2.157E-02	9.167E-01	4.021E 02	-1.683E-02	-8.417E 02	7.605E-01	7.602E-01
0.820	7.262E-01	6.950E-01	-2.445E-02	9.238E-01	4.261E 02	-1.947E-02	-9.735E 02	7.797E-01	7.793E-01
0.860	7.825E-01	7.634E-01	-3.063E-02	9.369E-01	5.224E 02	-2.533E-02	-1.267E 03	8.159E-01	8.152E-01
0.880	8.115E-01	7.977E-01	-3.395E-02	9.437E-01	5.735E 02	-2.863E-02	-1.432E 03	8.354E-01	8.344E-01
0.920	8.713E-01	8.655E-01	-4.100E-02	9.572E-01	7.957E 02	-3.605E-02	-1.802E 03	8.748E-01	8.735E-01
0.940	9.021E-01	8.994E-01	-4.475E-02	9.654E-01	9.093E 02	-4.027E-02	-2.014E 03	8.994E-01	8.978E-01
0.960	9.663E-01	9.667E-01	-5.266E-02	9.846E-01	1.743E 03	-5.066E-02	-2.533E 03	9.574E-01	9.549E-01
SHOC 1.000	1.000E 00	1.000E 00	-5.684E-02	1.000E 00	2.160E 03	-5.604E-02	-2.842E 03	1.004E 00	1.001E 00

-SHOCK LAYER GAS PROPERTIES-

ETA	Y/D	P (ATM.)	T (DEG.KEL.)	RHO (SLUGS/FT3)	MU (LBM/FT-SEC).	RMU (LBF2-SEC3/FT6)	K (BTU/FT-SEC-
0.0	0.0	2.9975E-01	3.4500E 03	2.0731E-05	5.7646E-05	9.4790E-11	8.5899E-05
0.0325	9.3761E-03	2.9975E-01	3.4821E 03	2.8015E-05	5.7978E-05	9.3974E-11	8.3463E-05
0.0625	1.8257E-02	2.9975E-01	3.5160E 03	2.7294E-05	5.8326E-05	9.3139E-11	8.0550E-05
0.0862	2.5470E-02	2.9975E-01	3.5475E 03	2.6620E-05	5.8645E-05	9.2391E-11	7.7605E-05
0.1200	3.6060E-02	2.9975E-01	3.5995E 03	2.5571E-05	5.9166E-05	9.1216E-11	7.2404E-05
0.1500	4.5884E-02	2.9975E-01	3.6581E 03	2.4437E-05	5.9744E-05	8.9990E-11	6.6379E-05
0.1800	5.6226E-02	2.9975E-01	3.7312E 03	2.3080E-05	6.0457E-05	8.8600E-11	5.9052E-05
0.2100	6.7311E-02	2.9975E-01	3.8331E 03	2.1291E-05	6.1438E-05	8.6908E-11	5.0185E-05
0.2400	7.9507E-02	2.9975E-01	3.9736E 03	1.9090E-05	6.2776E-05	8.4961E-11	4.1194E-05
0.2600	8.8548E-02	2.9975E-01	4.1085E 03	1.7217E-05	6.4051E-05	8.3391E-11	3.6450E-05
0.3000	1.0498E-01	2.9975E-01	4.4470E 03	1.3725E-05	6.7201E-05	8.0698E-11	4.3940E-05
0.3300	1.2910E-01	2.9975E-01	4.7109E 03	1.2071E-05	6.9641E-05	7.7749E-11	6.6638E-05
0.3400	1.3599E-01	2.9975E-01	4.7944E 03	1.1689E-05	7.0423E-05	7.7009E-11	7.6196E-05
0.3575	1.4854E-01	2.9975E-01	4.9382E 03	1.1134E-05	7.1796E-05	7.5714E-11	9.5619E-05
0.3725	1.5977E-01	2.9975E-01	5.0575E 03	1.0747E-05	7.2966E-05	7.4607E-11	1.1491E-04
0.3900	1.7334E-01	2.9975E-01	5.1941E 03	1.0362E-05	7.4354E-05	7.3289E-11	1.4090E-04
0.4000	1.8132E-01	2.9975E-01	5.2711E 03	1.0162E-05	7.5164E-05	7.2517E-11	1.5747E-04
0.4200	1.9772E-01	2.9975E-01	5.4765E 03	9.7787E-06	7.6877E-05	7.0883E-11	1.9511E-04
0.4400	2.1473E-01	2.9975E-01	5.5866E 03	9.4576E-06	7.8772E-05	6.9089E-11	2.3908E-04
0.4600	2.3239E-01	2.9975E-01	5.7729E 03	9.0872E-06	8.1185E-05	6.6857E-11	2.9455E-04
0.4800	2.5078E-01	2.9975E-01	5.9731E 03	8.7158E-06	8.4068E-05	6.4311E-11	3.5365E-04
0.5000	2.7000E-01	2.9975E-01	6.1906E 03	8.3301E-06	8.7565E-05	6.1457E-11	4.0135E-04
0.5050	2.7455E-01	2.9975E-01	6.2630E 03	8.2066E-06	8.8812E-05	6.0507E-11	4.1894E-04
0.5100	2.7998E-01	2.9975E-01	6.3455E 03	8.0688E-06	9.0278E-05	5.9440E-11	4.2914E-04
0.5125	2.8253E-01	2.9975E-01	6.4163E 03	7.7528E-06	9.1568E-05	5.8543E-11	4.3400E-04
0.5150	2.8513E-01	2.9975E-01	6.5620E 03	7.6115E-06	9.3167E-05	5.7487E-11	4.3474E-04
0.5200	2.9049E-01	2.9975E-01	6.7314E 03	7.4505E-06	9.7555E-05	5.4907E-11	4.0902E-04
0.5250	2.9617E-01	2.9975E-01	7.0727E 03	6.9732E-06	1.0401E-04	5.1926E-11	3.1863E-04
0.5300	3.0228E-01	2.9975E-01	7.5468E 03	6.4383E-06	1.1205E-04	4.9406E-11	1.9174E-04
0.5337	3.0723E-01	2.9975E-01	8.0262E 03	5.9894E-06	1.1889E-04	4.7929E-11	1.3168E-04
0.5375	3.1254E-01	2.9975E-01	8.5096E 03	5.5902E-06	1.2446E-04	4.6869E-11	1.5195E-04
0.5450	3.2383E-01	2.9975E-01	8.8911E 03	5.2994E-06	1.2820E-04	4.5587E-11	2.2104E-04
0.5487	3.2961E-01	2.9975E-01	8.9452E 03	5.3190E-06	1.2878E-04	4.5419E-11	2.3423E-04
0.5525	3.3544E-01	2.9975E-01	9.2403E 03	5.2124E-06	1.3128E-04	4.4548E-11	3.0755E-04
0.5562	3.4135E-01	2.9975E-01	9.4026E 03	5.1823E-06	1.3261E-04	4.4034E-11	3.5427E-04
0.5581	3.4430E-01	2.9975E-01	9.4718E 03	5.1741E-06	1.3316E-04	4.3806E-11	3.7514E-04
0.5641	3.5369E-01	2.9975E-01	9.6346E 03	5.1712E-06	1.3438E-04	4.3247E-11	4.2705E-04
0.5700	3.6306E-01	2.9975E-01	9.7592E 03	5.2045E-06	1.3525E-04	4.2793E-11	4.6963E-04
0.5800	3.7850E-01	2.9975E-01	1.0202E 04	5.1260E-06	1.3776E-04	4.0960E-11	6.4304E-04
0.5825	3.8290E-01	2.9975E-01	1.0300E 04	5.1134E-06	1.3817E-04	4.0459E-11	6.6603E-04
0.5850	3.8690E-01	2.9975E-01	1.0398E 04	5.1016E-06	1.3851E-04	4.0021E-11	7.3173E-04
0.5875	3.9092E-01	2.9975E-01	1.0509E 04	5.0831E-06	1.3883E-04	3.9447E-11	7.8564E-04
0.5950	4.0308E-01	2.9975E-01	1.0879E 04	5.0136E-06	1.3921E-04	3.7338E-11	9.8110E-04
0.6000	4.1126E-01	2.9975E-01	1.1075E 04	4.9927E-06	1.3893E-04	3.6084E-11	1.0946E-03
0.6200	4.4383E-01	2.9975E-01	1.1524E 04	5.0586E-06	1.3685E-04	3.2078E-11	1.3728E-03
0.6300	4.5990E-01	2.9975E-01	1.1671E 04	5.1238E-06	1.3569E-04	3.1733E-11	1.4671E-03
0.6600	5.0652E-01	2.9975E-01	1.1870E 04	5.4176E-06	1.3371E-04	3.0123E-11	1.5942E-03
0.6800	5.3619E-01	2.9975E-01	1.1975E 04	5.6206E-06	1.3245E-04	2.9239E-11	1.6609E-03
0.7000	5.6486E-01	2.9975E-01	1.2121E 04	5.8006E-06	1.3048E-04	2.7989E-11	1.7513E-03
0.7400	6.1972E-01	2.9975E-01	1.2421E 04	6.1441E-06	1.2557E-04	2.5352E-11	1.9236E-03
0.7600	6.4559E-01	2.9975E-01	1.2548E 04	6.3214E-06	1.2315E-04	2.4221E-11	1.9088E-03
0.8000	6.9891E-01	2.9975E-01	1.2759E 04	6.0541E-06	1.1964E-04	2.2324E-11	2.0841E-03
0.8200	7.2624E-01	2.9975E-01	1.2859E 04	5.9293E-06	1.1633E-04	2.1435E-11	2.1220E-03
0.8600	7.8254E-01	2.9975E-01	1.3040E 04	5.7045E-06	1.1183E-04	1.9827E-11	2.1780E-03
0.8800	8.1153E-01	2.9975E-01	1.3125E 04	5.5705E-06	1.0933E-04	1.8996E-11	2.2000E-03
0.9200	8.7127E-01	2.9975E-01	1.3323E 04	5.3732E-06	1.0414E-04	1.7393E-11	2.2272E-03
0.9400	9.0210E-01	2.9975E-01	1.3438E 04	5.2446E-06	1.0081E-04	1.6433E-11	2.2329E-03
0.9800	9.6629E-01	2.9975E-01	1.3705E 04	4.9630E-06	9.2772E-05	1.4311E-11	2.2131E-03
1.0000	1.0000E 00	2.9975E-01	1.3919E 04	4.7537E-06	6.6098E-05	1.2721E-11	2.1644E-03

-SPECIES MASS FRACTIONS-

	O2	N2	O	N	O+	N+	E-
0.0	9.2508E-15	1.8423E-02	8.2049E-08	3.0559E-06	2.6034E-22	8.1298E-22	5.0372E-20
0.0328	1.1307E-14	1.7743E-02	9.7031E-08	3.4942E-05	2.3206E-22	7.0168E-21	9.2449E-18
0.0625	1.3603E-14	1.7279E-02	1.1633E-07	4.0690E-05	3.5219E-22	2.1758E-21	5.8129E-16
0.0862	1.6150E-14	1.6827E-02	1.3821E-07	4.6944E-05	3.6157E-22	1.9551E-21	2.0376E-14
0.1200	2.0043E-14	1.6057E-02	1.7863E-07	5.8124E-05	2.7334E-20	2.8762E-20	7.1981E-15
0.1500	2.7895E-14	1.5109E-02	2.3919E-07	7.3664E-05	1.4732E-20	1.4597E-20	1.3511E-13
0.1800	4.0366E-14	1.3858E-02	3.4947E-07	9.8840E-05	3.7770E-22	1.6581E-21	7.7762E-12
0.2100	7.2033E-14	1.2162E-02	6.0588E-07	1.4736E-04	4.2885E-19	2.0287E-18	1.2902E-09
0.2400	1.4750E-13	1.0130E-02	1.1912E-06	2.3802E-04	9.4230E-18	1.5132E-16	3.1165E-09
0.2600	3.1497E-13	8.7119E-03	2.3382E-06	3.7148E-04	3.4131E-16	1.4717E-14	3.5270E-09
0.3000	2.2397E-12	7.6401E-03	1.1885E-05	1.0827E-03	2.1776E-14	1.0667E-12	3.1731E-09
0.3300	1.6676E-11	6.9772E-03	5.0068E-05	2.5946E-03	1.7674E-12	6.9827E-11	3.9660E-09
0.3400	3.1690E-11	5.6431E-03	7.7517E-05	3.3678E-03	6.6891E-12	2.1628E-10	4.4200E-09
0.3575	8.9885E-11	1.0877E-02	1.5963E-04	5.1484E-03	2.8961E-11	7.5001E-10	5.7865E-09
0.3725	2.0924E-10	1.1815E-02	2.8514E-04	7.1314E-03	8.9783E-11	1.9172E-09	7.3168E-09
0.3900	5.8050E-10	1.2541E-02	5.5823E-04	1.0063E-02	3.4396E-10	5.5247E-09	9.7896E-09
0.4000	9.0765E-10	1.2806E-02	7.6305E-04	1.1880E-02	5.9174E-10	8.5370E-09	1.1522E-08
0.4200	2.5611E-09	1.2584E-02	1.5385E-03	1.6373E-02	2.1066E-09	2.2707E-08	1.6162E-08
0.4400	6.5683E-09	1.1690E-02	2.8873E-03	2.1275E-02	6.5958E-09	5.2300E-08	2.2434E-08
0.4600	2.3625E-08	9.5551E-03	6.5750E-03	2.7828E-02	3.1987E-08	1.4980E-07	3.4722E-08
0.4800	6.9008E-08	7.1012E-03	1.3460E-02	3.3987E-02	1.2114E-07	3.5410E-07	5.2422E-08
0.5000	1.7701E-07	5.2013E-03	2.2626E-02	4.2591E-02	3.3932E-07	7.0939E-07	6.9193E-08
0.5050	2.5864E-07	4.4892E-03	2.8326E-02	4.3592E-02	5.6536E-07	9.2877E-07	7.9955E-08
0.5100	3.4856E-07	3.6677E-03	3.5123E-02	4.4692E-02	6.6714E-07	1.2010E-06	9.3225E-08
0.5125	4.3216E-07	3.0383E-03	4.1287E-02	4.5538E-02	1.1778E-06	1.4594E-06	1.0540E-07
0.5150	5.5709E-07	2.4804E-03	5.0141E-02	4.6299E-02	1.8148E-06	1.8969E-06	1.2394E-07
0.5200	8.8756E-07	1.3927E-03	7.4714E-02	4.7806E-02	4.5866E-06	3.5044E-06	1.8453E-07
0.5250	1.1675E-06	6.0140E-04	1.0763E-01	4.8960E-02	1.2461E-05	7.5153E-06	3.1137E-07
0.5300	9.8802E-07	2.0808E-04	1.3224E-01	4.9573E-02	4.0180E-05	2.1167E-05	6.1827E-07
0.5337	6.9046E-07	7.8279E-05	1.4181E-01	4.9773E-02	1.0101E-04	5.3310E-05	1.1297E-06
0.5375	4.6233E-07	3.2730E-05	1.4459E-01	4.9798E-02	2.1808E-04	1.1991E-04	1.8988E-06
0.5450	3.3698E-07	1.7140E-05	1.4589E-01	4.9741E-02	3.7153E-04	2.1227E-04	2.7472E-06
0.5487	1.2228E-07	1.5567E-05	1.4596E-01	4.9721E-02	4.1194E-04	2.3594E-04	2.9199E-06
0.5525	2.5737E-07	9.8136E-06	1.4614E-01	4.9612E-02	6.1012E-04	3.5828E-04	3.7876E-06
0.5562	2.2635E-07	7.5355E-06	1.4615E-01	4.9537E-02	7.4018E-04	4.3951E-04	4.3120E-06
0.5581	2.1643E-07	6.9566E-06	1.4710E-01	4.9485E-02	8.2836E-04	4.9216E-04	4.5974E-06
0.5641	1.9215E-07	5.5170E-06	1.4600E-01	4.9372E-02	1.0075E-03	6.0964E-04	5.2333E-06
0.5700	1.7569E-07	4.6186E-06	1.4589E-01	4.9208E-02	1.1731E-03	7.1572E-04	5.7592E-06
0.5800	1.2823E-07	2.4622E-06	1.4526E-01	4.8793E-02	1.3187E-03	1.1965E-03	7.8350E-06
0.5825	1.2053E-07	2.1657E-06	1.4501E-01	4.8617E-02	2.1094E-03	1.3740E-03	8.4182E-06
0.5850	1.1307E-07	1.9305E-06	1.4475E-01	4.8438E-02	2.4641E-03	1.5534E-03	8.9854E-06
0.5875	1.2525E-06	9.1872E-04	2.0593E-01	7.1985E-01	1.5255E-02	5.3393E-02	2.6194E-06
0.5950	1.2525E-06	6.0218E-04	2.0045E-01	7.0988E-01	2.3737E-02	7.2580E-02	3.5606E-06
0.6000	5.9328E-07	4.8613E-04	1.9699E-01	6.8897E-01	2.4202E-02	8.4706E-02	4.1555E-06
0.6200	8.5696E-07	3.0582E-04	1.8744E-01	6.5575E-01	3.3745E-02	1.1811E-01	5.7941E-06
0.6300	5.9328E-07	2.6435E-04	1.8380E-01	6.4303E-01	3.7391E-02	1.3087E-01	6.4202E-06
0.6600	3.9552E-07	2.1797E-04	1.7845E-01	6.2434E-01	4.2743E-02	1.4960E-01	7.3392E-06
0.6800	7.2512E-07	1.9773E-04	1.7540E-01	6.1365E-01	4.5794E-02	1.6028E-01	7.6630E-06
0.7000	5.2736E-07	1.7235E-04	1.7094E-01	5.9811E-01	5.0252E-02	1.7588E-01	8.0285E-06
0.7400	5.9328E-07	1.3220E-04	1.6095E-01	5.6320E-01	6.0236E-02	2.1081E-01	1.0343E-05
0.7600	5.9328E-07	1.1024E-04	1.5641E-01	5.4732E-01	6.4770E-02	2.2672E-01	1.1123E-05
0.8000	3.9552E-07	9.8863E-05	1.4842E-01	5.1938E-01	7.2768E-02	2.5469E-01	1.2494E-05
0.8200	3.9552E-07	9.0961E-05	1.4451E-01	5.0568E-01	7.6684E-02	2.6839E-01	1.3167E-05
0.8600	1.9776E-07	7.8387E-05	1.3713E-01	4.7989E-01	8.4057E-02	2.9420E-01	1.4443E-05
0.8800	1.9776E-07	7.2850E-05	1.3116E-01	4.6600E-01	8.6026E-02	3.0809E-01	1.5114E-05
0.9200	5.2736E-07	6.2813E-05	1.2518E-01	4.3808E-01	9.6006E-02	3.3602E-01	1.6484E-05
0.9400	5.2736E-07	5.7391E-05	1.2020E-01	4.2063E-01	1.0599E-01	3.5348E-01	1.7341E-05
0.9800	3.2960E-07	4.7240E-05	1.0854E-01	3.7995E-01	1.1265E-01	3.9427E-01	1.9342E-05
1.0000	3.2960E-07	4.0376E-05	9.0211E-02	3.4720E-01	1.2196E-01	4.2653E-01	2.0944E-05

-SPECIES MASS FRACTIONS-

ETA	C	H	H2	CO	C3-G	CN	C2H	C2H2
0.0	4.9362E-03	2.8526E-02	2.4502E-02	2.5782E-01	4.5658E-02	2.9809E-02	1.8419E-01	4.5262E-02
0.3250	5.9374E-03	3.0181E-02	2.3256E-02	2.5781E-01	5.0327E-02	3.2711E-02	1.8838E-01	4.1174E-02
0.6250	7.1987E-03	3.1926E-02	2.1939E-02	2.5780E-01	5.5469E-02	3.5087E-02	1.9239E-01	3.7140E-02
0.8625	8.6290E-03	3.3558E-02	2.0726E-02	2.5779E-01	6.0603E-02	3.7322E-02	1.9550E-01	3.3677E-02
1.2000	1.1274E-02	3.6225E-02	1.8770E-02	2.5778E-01	6.9303E-02	4.1004E-02	1.9989E-01	2.8297E-02
1.5000	1.5235E-02	3.9213E-02	1.6654E-02	2.5778E-01	8.0011E-02	4.5227E-02	2.0259E-01	2.3113E-02
1.8000	2.2345E-02	4.2883E-02	1.4210E-02	2.5776E-01	9.4201E-02	5.0433E-02	2.0200E-01	1.7721E-02
2.1000	3.7840E-02	4.7796E-02	1.1288E-02	2.5776E-01	1.1265E-01	5.7108E-02	1.9309E-01	1.1908E-02
2.4000	6.8909E-02	5.4027E-02	8.0147E-03	2.5775E-01	1.2993E-01	6.4788E-02	1.6963E-01	6.3510E-03
2.6000	1.1468E-01	5.9271E-02	5.6784E-03	2.5775E-01	1.2997E-01	7.0053E-02	1.3606E-01	3.2614E-03
3.0000	2.8215E-01	6.8072E-02	2.2558E-03	2.5774E-01	6.7145E-02	7.4607E-02	5.0150E-02	3.5577E-04
3.3000	4.1257E-01	7.0919E-02	1.1483E-03	2.5767E-01	2.2302E-02	7.0488E-02	1.5867E-02	5.9470E-05
3.4000	4.4489E-01	7.1375E-02	9.3210E-04	2.5762E-01	1.4693E-02	6.8020E-02	1.0622E-02	3.1846E-05
3.5750	4.0988E-01	7.1889E-02	6.6C03E-04	2.5748E-01	6.0730E-03	6.2671E-02	5.2276E-03	1.0831E-05
3.7250	5.1821E-01	7.2149E-02	5.0279E-04	2.5726E-01	3.5850E-03	5.7381E-02	2.8900E-03	4.3612E-06
3.9000	5.4282E-01	7.2337E-02	3.7404E-04	2.5679E-01	1.7008E-03	5.0694E-02	1.4791E-03	1.6954E-06
4.0000	5.5455E-01	7.2419E-02	3.1459E-04	2.5643E-01	1.0100E-03	4.6274E-02	9.4216E-04	8.0788E-07
4.2000	5.7178E-01	7.2518E-02	2.3318E-04	2.5502E-01	4.8912E-04	3.8959E-02	4.8950E-04	3.4613E-07
4.4000	5.8552E-01	7.2589E-02	1.7255E-04	2.5272E-01	1.7710E-04	3.1590E-02	2.1258E-04	5.8367E-08
4.6000	5.9872E-01	7.2642E-02	1.2439E-04	2.4726E-01	8.6503E-05	2.3406E-02	1.0714E-04	3.9342E-08
4.8000	6.1143E-01	7.2681E-02	8.9161E-05	2.3421E-01	3.4308E-05	1.6517E-02	4.7722E-05	1.1700E-08
5.0000	6.2694E-01	7.2710E-02	6.2584E-05	2.1816E-01	1.4073E-05	4.0912E-03	2.0741E-05	3.9326E-09
5.0500	6.3193E-01	7.2716E-02	5.6511E-05	2.0818E-01	1.0573E-05	3.5557E-03	1.6170E-05	2.6349E-09
5.1000	6.3771E-01	7.2722E-02	5.0066E-05	1.9629E-01	7.6038E-06	3.0398E-03	1.2110E-05	1.7408E-09
5.1250	6.4282E-01	7.2728E-02	4.5047E-05	1.8545E-01	5.5615E-06	2.6387E-03	9.2340E-06	1.1604E-09
5.1500	6.4575E-01	7.2734E-02	4.0134E-05	1.7000E-01	4.1924E-06	2.2618E-03	7.1601E-06	8.2319E-10
5.2000	6.6832E-01	7.2747E-02	2.9501E-05	1.2698E-01	1.8472E-06	1.4790E-03	3.4673E-06	2.9195E-10
5.2500	6.9159E-01	7.2759E-02	1.9243E-05	6.9344E-02	5.9104E-07	7.9914E-04	1.2727E-06	5.7271E-11
5.3000	7.0434E-01	7.2767E-02	1.1552E-05	2.6210E-02	1.3598E-07	3.6688E-04	2.5334E-07	1.1493E-11
5.3375	7.0091E-01	7.2772E-02	7.3137E-06	9.1658E-03	3.4162E-08	1.7633E-04	1.0755E-07	2.2213E-12
5.3750	6.8692E-01	7.2776E-02	4.8719E-06	3.5944E-03	9.6551E-09	9.0325E-05	3.6636E-08	5.0098E-13
5.4500	6.6944E-01	7.2777E-02	3.6105E-06	1.7431E-03	3.6741E-09	5.4429E-05	1.6238E-08	1.5926E-13
5.4875	6.6580E-01	7.2784E-02	3.4637E-06	1.5602E-03	3.1548E-09	5.0559E-05	1.4274E-08	1.3615E-13
5.5250	6.4737E-01	7.2789E-02	2.8139E-06	9.1890E-04	1.4553E-09	3.5116E-05	7.7158E-09	5.2357E-14
5.5625	6.3617E-01	7.2793E-02	2.5034E-06	6.8100E-04	1.0167E-09	2.8362E-05	5.5103E-09	3.9288E-14
5.5812	6.3000E-01	7.2795E-02	2.4028E-06	6.2717E-04	9.3549E-10	2.6543E-05	5.0708E-09	3.3713E-14
5.6406	6.1647E-01	7.2799E-02	2.1574E-06	4.7667E-04	6.1337E-10	2.1011E-05	3.0399E-09	2.1849E-14
5.7000	6.0521E-01	7.2801E-02	1.9903E-06	3.8794E-04	4.5833E-10	1.8793E-05	2.8567E-09	1.5886E-14
5.8000	5.6385E-01	7.2805E-02	1.5026E-06	1.8571E-04	1.5907E-10	1.0961E-05	1.1843E-09	5.0845E-15
5.8250	5.4045E-01	7.2808E-02	1.4231E-06	1.6100E-04	1.2503E-10	9.8511E-06	9.8719E-10	3.8709E-15
5.8500	5.3642E-01	7.2808E-02	1.3447E-06	1.3907E-04	1.0126E-10	8.8053E-06	6.2647E-10	3.1173E-15
5.8750	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
5.9500	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
6.0000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
6.2000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
6.3000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
6.6000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
6.8000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
7.0000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
7.4000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
7.6000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
8.0000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
8.2000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
8.6000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
8.8000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
9.2000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
9.4000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
9.8000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20
10.0000	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20

-SPECIES MASS FRACTIONS-

ETA	CP	C3H	C4H	HCN	C2	C4	AMW
0.0	1.0884E 00	1.7817E-01	1.4154E-01	2.9896E-02	1.1239E-02	2.2441E-17	1.3984E 01
0.3250	1.0653E 00	1.7471E-01	1.3637E-01	2.8182E-02	1.3189E-02	1.5087E-17	1.3763E 01
0.6250	1.0359E 00	1.7071E-01	1.3085E-01	2.6593E-02	1.5582E-02	3.1055E-17	1.3534E 01
0.8625	1.0048E 00	1.6651E-01	1.2540E-01	2.5131E-02	1.8205E-02	7.1570E-17	1.3323E 01
1.2000	9.4741E-01	1.5917E-01	1.1647E-01	2.2705E-02	2.2940E-02	4.8490E-16	1.2986E 01
1.5000	8.7796E-01	1.4947E-01	1.0568E-01	2.0177E-02	2.9671E-02	3.4414E-16	1.2612E 01
1.8000	7.9096E-01	1.3526E-01	9.1310E-02	1.7129E-02	4.0782E-02	2.3976E-16	1.2150E 01
2.1000	6.8219E-01	1.1246E-01	7.0615E-02	1.3379E-02	6.1725E-02	5.1549E-13	1.1514E 01
2.4000	5.7290E-01	8.0073E-02	4.4389E-02	9.1495E-03	9.6610E-02	6.1521E-11	1.0702E 01
2.6000	5.1512E-01	5.0868E-02	2.4132E-02	6.1592E-03	1.3303E-01	9.2047E-09	9.9798E 00
3.0000	5.2485E-01	8.9659E-03	2.4484E-03	2.1259E-03	1.7521E-01	5.2371E-07	8.6109E 00
3.3000	6.4827E-01	1.4071E-03	1.9283E-04	9.1174E-04	1.3483E-01	1.2754E-05	8.0229E 00
3.4000	7.0741E-01	7.4461E-04	9.1157E-05	6.9800E-04	1.1717E-01	2.3105E-05	7.9063E 00
3.5750	8.3401E-01	2.4227E-04	8.3107E-06	4.3991E-04	8.8386E-02	4.6778E-05	7.7570E 00
3.7250	9.6468E-01	9.1123E-05	6.1392E-06	2.9930E-04	6.6311E-02	7.7730E-05	7.6607E 00
3.9000	1.1452E 00	3.3958E-05	6.4810E-07	1.9150E-04	5.0287E-02	1.3090E-04	7.5931E 00
4.0000	1.2624E 00	1.4694E-05	7.1068E-07	1.4420E-04	4.1687E-02	1.6474E-04	7.5574E 00
4.2000	1.5342E 00	6.6200E-06	3.4463E-08	8.8045E-05	2.9578E-02	2.6910E-04	7.5018E 00
4.4000	1.8624E 00	1.9425E-07	3.6347E-08	4.9801E-05	2.0707E-02	4.0646E-04	7.4542E 00
4.6000	2.2980E 00	5.5825E-07	3.7295E-09	2.6792E-05	1.3992E-02	6.7299E-04	7.4012E 00
4.8000	2.8012E 00	9.6371E-08	1.3178E-09	1.3191E-05	9.4553E-03	1.0598E-03	7.3449E 00
5.0000	3.3169E 00	4.3905E-08	6.0035E-11	6.3035E-06	6.1455E-03	1.4242E-03	7.2754E 00
5.0500	3.4617E 00	2.9576E-08	1.4361E-10	5.0075E-06	5.4556E-03	1.6583E-03	7.2515E 00
5.1000	3.6001E 00	1.8803E-08	7.9362E-11	3.6991E-06	4.7321E-03	1.9454E-03	7.2230E 00
5.1250	3.6907E 00	1.2039E-08	4.3313E-11	2.7735E-06	4.1752E-03	2.2144E-03	7.1991E 00
5.1500	3.7596E 00	6.3551E-09	2.7655E-11	2.1095E-06	3.6604E-03	2.6189E-03	7.1658E 00
5.2000	3.6934E 00	2.7160E-09	3.1009E-12	9.5283E-07	2.5743E-03	3.9444E-03	7.0761E 00
5.2500	3.0054E 00	2.5986E-10	7.7493E-13	3.1155E-07	1.5640E-03	6.7124E-03	6.9583E 00
5.3000	1.8243E 00	7.6602E-11	5.2820E-14	7.5164E-08	8.2191E-04	1.3398E-02	6.8550E 00
5.3375	1.1632E 00	1.2527E-11	4.6795E-15	2.0211E-08	4.4145E-04	2.4437E-02	6.7826E 00
5.3750	9.6836E-01	2.2923E-12	4.8119E-16	6.1436E-09	2.4609E-04	4.1207E-02	6.7084E 00
5.4500	9.9698E-01	5.2739E-13	2.3309E-17	2.4860E-09	1.5630E-04	5.9579E-02	6.6363E 00
5.4875	1.0109E 00	5.1901E-13	5.6273E-17	2.1556E-09	1.4623E-04	6.3393E-02	6.7157E 00
5.5250	1.1110E 00	5.6297E-14	2.0857E-17	1.0011E-09	1.0461E-04	8.2048E-02	6.7952E 00
5.5625	1.1869E 00	1.1759E-13	1.0915E-17	7.4554E-10	8.5738E-05	9.3362E-02	6.8746E 00
5.5812	1.2223E 00	9.5452E-14	9.5086E-18	6.7182E-10	8.0317E-05	9.9531E-02	6.9142E 00
5.6406	1.3184E 00	5.5590E-14	4.5101E-18	4.6732E-10	6.6574E-05	1.1117E-01	7.0400E 00
5.7000	1.4000E 00	3.7782E-14	2.8769E-18	3.5617E-10	5.7629E-05	1.2444E-01	7.1659E 00
5.8000	1.7511E 00	9.1190E-15	1.2441E-19	1.3230E-10	3.3759E-05	1.6094E-01	7.3777E 00
5.8250	1.8423E 00	6.1419E-15	2.4282E-19	1.0630E-10	3.0242E-05	1.8134E-01	7.4306E 00
5.8500	1.9375E 00	4.7174E-15	1.6674E-19	8.6970E-11	2.6935E-05	1.9239E-01	7.4835E 00
5.8750	2.0524E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	7.5360E 00
5.9500	2.4771E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	7.6954E 00
6.0000	2.7256E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	7.8013E 00
6.2000	3.3700E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	8.2250E 00
6.4000	3.5951E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	8.4368E 00
6.6000	3.9001E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	9.0723E 00
6.8000	4.0752E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	9.4960E 00
7.0000	4.3084E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	9.9196E 00
7.4000	4.7772E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0767E 01
7.6000	4.9057E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.1191E 01
8.0000	5.2592E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0986E 01
8.2000	5.3849E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0743E 01
8.6000	5.5888E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0484E 01
8.8000	5.6003E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0345E 01
9.2000	5.8249E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0085E 01
9.4000	5.8879E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	9.9124E 00
9.8000	5.9511E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	9.5856E 00
10.0000	5.9141E 00	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	1.0000E-20	9.3250E 00

```
C     **  VISCOUS HYPERSONIC SHOCK LAYER / COUPLED CONVECTIVE
C         AND RADIATIVE HEAT TRANSFER COMPUTER PROGRAM  **
C                     VISRAD III       C. ENGEL 6/71
C
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /MAIN/KEEP,MAXE,MAXM,MAXD,IDEBUG,MCONV,ECONV,DCONV,LT,IAB
      LOGICAL MCONV,ECONV,DCONV
C
C                                                           **
C     **          D R I V E R    P R O G R A M
C
C
    1 CONTINUE
C
C     **  READ AND PRINT ALL INPUT DATA  **
C
      CALL INPUT
C
C     **  COMPUTE NECESSARY INITIAL QUANTITIES  **
C
      CALL INIT
      IEM = 0
C
C
C     **  SOLVE MOMENTUM EQUATION  **
C
 1000 CONTINUE
      IEM = IEM+1
C
      CALL MOMTM
C
C     **  CHECK FOR CONVERGENCE OF MOMENTUM ITERATION  **
C
      IF ( MCONV ) GO TO 1500
C
```

```
C
C     **  ERROR EXIT IF MOMENTUM ITERATION DOES NOT CONVERGE  **
C
      CALL ERROR ( 1 )
C
 1500 CONTINUE
C
C     **  SOLVE ENERGY EQUATION  **
C
      CALL ENERGY
C     **  INTERMEDIATE PRINTOUT OF TEMPERATURE ITERATION  **
C
      IF( IDEBUG.GT. 0 )                CALL OUTPUT(2)
C
C     **  CHECK FOR CONVERGENCE OF TEMPERATURE ITERATION  **
C
C
      IF( ECONV ) GO TO 2500
C
C     **  ERROR EXIT IF TEMPERATURE ITERATION DOES NOT CONVERGE  **
C
      CALL ERROR ( 2 )
C
 2500 CONTINUE
C
C     **  CHECK SIMULTANEOUS MOMENTUM AND ENERGY CONVERGENCE  **
C
      IF(IEM.LT. 5) GO TO 1000
      IF(IEM.GT.MAXD) GO TO 3000
      IF(.NOT.MCCNV) GO TO 1000
      IF(.NOT.ECCNV) GO TO 1000
      IF(.NOT.DCCNV) GO TO 1000
C     **  PRINT ALL OUTPUT  **
C
      CALL OUTPUT ( 1 )
C
```

```
C       **  CONVERGED . GO BACK TO RUN ANOTHER CASE  **                    MAIN 730
C                                                                         MAIN 740
        GO TO 1                                                           MAIN 750
C                                                                         MAIN 760
 3000 CONTINUE                                                            MAIN 770
C                                                                         MAIN 780
C       **  MOMENTUM AND ENERGY DID NOT CONVERGE SIMULTANEOUSLY  **       MAIN 790
C                                                                         MAIN 800
        CALL ERROR(3)                                                     MAIN 810
        CALL OUTPUT (3)                                                   MAIN 820
        GO TO 1                                                           MAIN 830
        END                                                               MAIN 840
```

```
      FUNCTION QUAD (X,FX,I)
C
C     **  TRAPEZOIDAL QUADRATURE FUNCTION  **
C
      DIMENSION X(60),FX(60)
      DX=X(I)-X(I-1)
      QUAD = (DX/2.0) * (FX(I) + FX(I-1) )
      RETURN
      END
```

```
      SUBROUTINE INPUT
C
C
C     **  ROUTINE TO READ AND PRINT ALL INPUT DATA  **
C
C
      COMMON /CONV/ FPRCT,TPRCT,DDAMP,TDAMP,PDTIL
      COMMON /DEL/ DELTA,DTIL,DTILS
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /MAIN/KEEP,MAXE,MAXM,MAXD,IDEBUG,MCONV,ECONV,DCONV,LT,IAB
      COMMON/PRCP1/PI(60),RHO(60), T(60),AMW(60),C (20,60),CC(5,60)
      COMMON/PRCP2/  MU(60),RM(60), AK(60)
      COMMON/PRCP3/CPS(20,60),HS(20,60),CP (60),HM(60)
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON /RF/ DUD,DPHI,ID,RZB,PD,HD,HTOTAL
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON /YL/ETA(60),YCND(60)
C
C
      COMMON/EQ1/AI(20), BI(20), CI(20), DI(20), EI(20), FI(20), GI(20),
     X        AII(20),BII(20),CII(20),DII(20),EII(20),FII(20),GII(20)
      COMMON/EQ2/AA(20,5),ICODE(20)
      COMMON/EQ3/IA(20,5)
      COMMON/ID/SP(20),EL(5)
      COMMON/WT/SMW(20),AWT(5)
      COMMON/NUMBER/NSP,NNS,NE,NC
      COMMON/SP1/NDBUG
C
      REAL  MU,MUDZ
      LOGICAL MCONV,ECONV,DCONV
      DIMENSION TITLE(18)
      DATA END /'END '/
      IF ( TITLE ( 1 ) .EQ. END ) STOP
C
C
C
C     **  INPUT FORMATS  **
```

```
C
 100  FORMAT (18A4)
 101  FORMAT (9I5,2E12.0,2X,I1)
 102  FORMAT ( 6E12.0 )
 103  FORMAT(A4,6X, E10.4,20X,5F5.0,F10.5)
 104  FORMAT(7E10.4)
 105  FORMAT(A4,E16.8)
 106  FORMAT(6E10.4,I3)
 108  FORMAT(5E15.8)
C
C     **  OUTPUT FORMATS  **
C
 200  FORMAT ( 1H1 , 18A4 //// )
 201  FORMAT ( 12H0 INPUT DATA /// )
 202  FORMAT ( 9H0KEEP    = I5
     1        / 9H NETA    = I5
     2        / 9H MAXM    = I5
     3        / 9H MAXE    = I5
     4        / 9H MAXD    = I5
     5        / 9H FPRCT   = 1PE15.6
     6        / 9H TPRCT   = E15.6
     7        / 9H LT      = I5
     8        / 9H IDEBUG  = I5
     9        / 9H IPHI    = I5   )
 204  FORMAT ( 9H0UINF    = 1PE15.6
     1        / 9H RINF    = E15.6
     2        / 9H R       = E15.6
     3        / 9H TW      = E15.6
     4        / 9H HTOTAL  = E15.6
     5        / 9H RVW     = E15.6
     6        / 9H PCTIL   = E15.6 //)
C
 206  FORMAT ( 20H0INITIAL T PROFILE   / ( 1H , 12F10.5 )      )
 207  FORMAT ( 20H0INITIAL RHO PROFILE/ ( 1H , 12F10.5 )      )
 208  FORMAT ( 20H0INITIAL RM  PROFILE/ ( 1H , 12F10.5 )      )
 210  FORMAT(32H * CONVECTIVE CALCULATION ONLY * )
```

```
  211 FORMAT(36H * UNCOUPLED RADIATICN CALCULATION * )
  212 FORMAT(34H * COUPLED RADIATION CALCULATION * )
  213 FORMAT(36H * CONTINUUM AND LINE CALCULATION * )
  214 FORMAT(19H * EMISSION MODEL * )
  215 FORMAT(1X,'ABLATION PRODUCTS ARE INTRODUCED AT ITERATION IAB=',I3)
  216 FORMAT (16H SPECIES INPUTS
     1        /16H NO. ELEMENTS = I5
     2        /25X,5(I5,2X,A4)      )
  218 FORMAT (16H NO. SPECIES   = I5)
  220 FORMAT (25X,5(I5,2X,A4))
  222 FORMAT (16H NO. SOLIDS    = I5)
C
C CARD 1 -----------------------------------------------------------
      READ (5,100) TITLE
      WRITE ( 6,200 ) TITLE
C
C
C     **  INPUT OPTION PARAMETERS   **
C
C     **  IRAD = 1  NO RADIATION CALCULATED
C         IRAD = 2  UNCOUPLED SOLUTION
C         IRAD = 3  COUPLED SOLUTION   **
C     **  ITYPE=0 SPECTRAL MODEL WITH LINES
C         ITYPE=1 EMISSION MODEL
C
      KETA = NETA
C CARD 2 -----------------------------------------------------------
      READ (5,101)KEEP,NETA,IRAD,ITYPE,MAXM,MAXE,MAXD,LT,IPHI,
     1            FPRCT,TPRCT,IDEBUG
      META = NETA
      IF(KETA .EQ. 0) KEEP = 0
      IF(KEEP. GT. 0) NETA = KETA
C
      CDAMP = 0.5
      TDAMP = 0.6
      IF(MAXM .EQ. 0) MAXM=15
```

```
      IF(MAXE.EQ. 0) MAXE=15
      IF(MAXD.EQ. 0) MAXD=15
      IF(FPRCT.EQ. C.0) FPRCT=.005
      IF(TPRCT .EQ. C.0) TPRCT=0.005
      IF ( NETA .EQ. 0 ) NETA = 51
      IF (IRAD.EQ.0) IRAD =1
C
      WRITE ( 6,201 )
      WRITE (6,202)KEEP,NETA,MAXN,MAXE,MAXD,FPRCT,TPRCT,LT,IDEBUG
     1              ,IPHI
C
C     **  FREE-STREAM FLIGHT CONDITIONS  **
C CARD 3 -----------------------------------------------------------------
      READ(5,102) U INF,R INF,R,TWK,HTOTAL,RVW
      UINF2=UINF**2
      IF(KEEP.GT. 0) TWOLD = T(1)
      T(1)=TWK
C
      IF(HTOTAL .EQ. C.0) HTOTAL=UINF2/2.0
C
C     **  INITIAL SHOCK QUANTITY ESTIMATES  **
C CARD 4 -----------------------------------------------------------------
      READ(5,102)     DELTA,DTIL,RZE,RE,PDTIL
      IF(PDTIL.EC.C.0) PDTIL = .001
      WRITE(6,204) U INF,R INF,R,TWK,HTOTAL,RVW,PDTIL
      IF (IRAD.EQ.1) WRITE (6,210)
      IF (IRAD.EQ.2) WRITE (6,211)
      IF (IRAD.EQ.3) WRITE (6,212)
      IF(IRAD.EC.1) GO TO 300
      IF( ITYPE.EQ.0) WRITE(6,213)
      IF( ITYPE.EQ.1) WRITE(6,214)
  300 CONTINUE
C
C     **   INPUT INITIAL TEMPERATURE PROFILE   **
C CARD 5 -----------------------------------------------------------------
      IF(LT .EQ. 0) GO TO 2800
```

```
      READ ( 5,102 ) ( T ( I ) , I = 1 , NETA )
      WRITE ( 6,206 ) ( T ( I ) , I = 1 , NETA )
      T(1) =TWK
 2800 CONTINUE
C     ** INPUT RHO AND (RHO)(MU) PROFILES   **
C CARD 6 -------------------------------------------------------------------
      IF(LT.LT.2) GO TO 2900
      READ(5,102) (RHO(I),I=1,NETA)
      READ(5,102) (RM (I),I=1,NETA)
      WRITE(6,207)(RHO(I),I=1,NETA)
      WRITE(6,208)(RM (I),I=1,NETA)
 2900 CONTINUE
C
C     **  SHOCK SHAPE (DEPS/DXI)   **
C
      IF (IPHI .NE. 0 ) GO TO 2550
      DEPS = 0.0
      GO TO 2570
 2550 CONTINUE
C CARD 7 -------------------------------------------------------------------
      READ(5,102)  DEPS
 2570 CONTINUE
      DPHI = 1. -DEPS
      WRITE(6,217)  DEPS
  217 FORMAT(9HODEPS/DXI  /(1H ,12F10.5) )
C
C
      IF ( META .GT. 0 ) GO TO 1000
      IF(KEEP .GT. 0) GO TO 1500
C
C     **  FIXED GRID SIZE ON ETA   **
C
      DETA = 0.02
      ETA ( 1 ) = 0.0
      DO 500 I = 2 , 51
      ETA ( I ) = ETA ( I-1 ) + DETA
```

```
                                                                        INPU1810
  500   CONTINUE                                                        INPU1820
C                                                                       INPU1830
        GO TO 1500                                                      INPU1840
C                                                                       INPU1850
 1000 CONTINUE                                                          INPU1860
C                                                                       INPU1870
C       **   INPUT ETA POINTS   **--------------------------------------INPU1880
C CARD 8 -------------------------------------------------------------- INPU1890
        READ ( 5,102 ) ( ETA ( I ) , I = 1 , NETA )                     INPU1900
C                                                                       INPU1910
 1500 CONTINUE                                                          INPU1920
C                                                                       INPU1930
C-----READ SPECIES PARAMETER CARDS......--------------------------------INPU1940
C CARD 9 -------------------------------------------------------------- INPU1950
        READ 101,NDBUG,IRS    ,IAB                                      INPU1960
        IF (IAB.LE. 0) IAB=6                                            INPU1970
        IAB = IAB-1                                                     INPU1980
        WRITE(6,215) IAB                                                INPU1990
        IF(IRS.EQ. 0) GO TO 20                                          INPU2000
C       NDBUG=OPTICNAL OUTPUT VARIABLE                                  INPU2010
C       NC = NUMBER OF GASEOUS COMPONENTS-------------------------------INPU2020
C CARD 10 ------------------------------------------------------------- INPU2030
        READ 108,(CWALL(I),I=1,NSP)                                     INPU2040
   20   CONTINUE                                                        INPU2050
        WRITE(6,216) NE,(I,EL(I),I=1,NE)                                INPU2060
        WRITE(6,218) NSP                                                INPU2070
        JJ = 1                                                          INPU2080
        KK = JJ+4                                                       INPU2090
   30   WRITE(6,220) (I,SP(I),I=JJ,KK)                                  INPU2100
        IF(KK+5.GT.NSP) GO TO 35                                        INPU2110
        JJ = JJ+5                                                       INPU2120
        KK = JJ +4                                                      INPU2130
        GO TO 30                                                        INPU2140
   35   KD = NSP -KK                                                    INPU2150
        IF(KD.LE.0) GO TO 45                                            INPU2160
        KK = KK +KD
```

```
      JJ = JJ +5
   40 GO TC 30
   45 CONTINUE
      WRITE(6,222) NNS
      PRINT 3C5                                                 2X,
  305 FORMAT(/' SPECIES'/' NAME',9X,'SMW',
     1'WALL MASS FRACTICN'/)
      DO10I=1,NSP
   10 PRINT3C2,SP(I),SMW(I),CWALL(I)
  302 FORMAT(1X,A4,1F13.3,E12.4)
      IF(NDBUG.EC.0)GOTC9999
      PRINT3C9
  309 FORMAT(//,' SPECIES',35X,'THERMO-CONSTANTS A-G',29X,'RANGE')
      DO11I=1,NSP
      PRINT3C3,SP(I),AII(I),BII(I),CII(I),DII(I),EII(I),FII(I),GII(I)
   11 PRINT304,         AI (I),BI (I),CI (I),DI (I),EI (I),FI (I),GI (I)
  303 FORMAT(/,1X,A4,7E12.4,'  LCW RANGE')
  304 FORMAT(     5X,7E12.4,'  HIGH RANGE')
      PRINT 3C7
  307 FORMAT(//,25X,' AA(I,J) MATRIX',/)
      DO12J=1,NE
   12 PRINT 306,(IA(I,J),I=1,NSP)
  306 FORMAT(5X,20I5)
 9999 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE INIT
C
C
C     **  ROUTINE TO COMPUTE NECESSARY INITIAL QUANTITIES
C
C
      COMMON /CCNV/ FPRCT,TPRCT,DCAMP,TCAMP,PDTIL
      COMMON /DEL/ DELTA,DTIL,DTILS
      COMMCN/EG2/AA(20,5),ICODE(20)
      COMMON/EQ3/IA(20,5)
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMCN/GUESS/TG1(60),TG2(60)
      COMMON /MAIN/KEEP,MAXE,MAXM,MAXD,IDEBUG,MCONV,ECONV,DCONV,LT,IAB
      COMMON /NCN/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/NUMBER/NSP,NNS,NE,NC
      COMMON/PRCP1/PI(60),RHC(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMON/PRCP2/  MU(60),RM(60), AK(60)
      COMMCN/PRCP3/CPS(20,60),HS(20,60),CP (60),HM(60)
      COMMON /OLD/ TOLD(60),EOLD(60)
      COMMON/VECTOR/ CA(60),CB(60),CC(60),B(60)
      COMMON /VEL/ F(60),FC(60),Z(60),V(60)
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON /RH/ DUD,DPHI,ID,RZB,PC,HD,FTOTAL
      COMMCN/SP2/BR,S(20),CSHOCK(5)
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON/WT/SMW(20),AWT(5)
      COMMON /YL/ETA(60),YCND(60)
      COMMCN /PROP4/ NFF,AAMW(60),AT(60)
      REAL  MU,MUDZ
C
      LOGICAL MCONV,ECONV,DCONV
C
      MCONV = .FALSE.
      ECONV = .FALSE.
      DCONV = .FALSE.
      DO 900 I=1,60
```

```
      DO 900 J=1,NSP
  900 C(J,I) = 1.0E-20
C
C
C     **  DETERMINE DENSITY RATIO , REYNOLDS NUMBER
C         FROM INPUTS OR RANKINE HUGONIOT EQS.   **
C
C GUESSED VALUES
      TD = 12000. + .5E-5*(HTOTAL -6.5E+8)
      RZB=.06
C
      T(NETA) = 1.0
      HNF = 2.*778.28*32.172/UINF2
  998 CONTINUE
      PD = (1. -RZB)*RINF *UINF2/2116.
      HD = HTOTAL/(778.28*32.172)
      CPNF = 1.8*778.28*32.172*TD *2.   /UINF2
      AKNF = 1.8*778.28*TD        *RZB/(R*RINF*UINF*UINF2)
      PI(NETA) = PD
      CALL GAS(NETA)
      RZB1=RINF/(RDZ*RHO(NETA) )
      TEST =ABS((RZB-RZB1)/RZB)
      IF(TEST .LT. 0.005) GO TO 999
      RZB=.5*(RZB+RZB1)
      GO TO 998
  999 CONTINUE
      RE = RDZ*UINF*R*32.174 / MUDZ
C
C
C     **  GUESS AT DELTA TO START   **
C
      IF(DELTA .EQ. 0.0) DELTA=0.78*RZB
      IF(DTIL .EQ. 0.0) DTIL=1.1*DELTA   +1.2*RVW
      WRITE(6,200) RZB,RE
  200 FORMAT(14H0DENSITY RATIO ,5X,12HREYNOLDS NO.  /2E15.6)
      WRITE(6,201) DELTA,DTIL
```

```
 201  FORMAT(6H0DELTA,13X,4HDTIL    /2E15.6)
C
 997  CONTINUE
      DO 995 I=1,NETA
      PI(I) = PD
      E(I) =0.0
 995  CONTINUE
C     **  RANKIN-HUGONIOT RELATIONS   **
C
      VD = -RZB
      TW = T(1)
      T(1) = T(1)/TD
C
C     **  STAGNATION POINT LIMIT QUANTITIES   **
C
      DUD = DPHI + RZB*(1.-DPHI)
C NONDIMENSIONALIZING FACTORS
      AKNF = 1.8*778.28*TD           *RZB/(R*RINF*UINF*UINF2)
      CPNF = 1.8*778.28*32.172*TD *2.   /UINF2
C
C GUESSED F AND Z PROFILES
C
      IF(KEEP. GT. 0) GO TO 9
      N = NETA-2
      FD = RZB/(2.*DUD*DTIL)
      FW = -RVW*FD
      F(1) = FW
      DO 2 K=2,NETA
      F(K) = (FD-FW)*ETA(K) + FW
    2 CONTINUE
      DO 3 I=1,N
      Z(I) = ETA(I+1)/DTIL
    3 CONTINUE
C GUESSED T PROFILES
      IF(KEEP.GT.0)GOTO9
      IF(LT.GT.0) GO TO 11
```

```
      IF(RVW.GT.0.0)GCTC7                                               INIT1090
C NO BLOWING T PRCFILE                                                  INIT1100
      TWG1 = .1C33                                                      INIT1110
      DO6K = 2,NETA                                                     INIT1120
      TP = TG1(K) +(T(1)- TWG1)                                         INIT1130
      T(K) = TP -(T(1)- TWG1) * ETA(K)                                  INIT1140
    6 CONTINUE                                                          INIT1150
      GO TO 11                                                          INIT1160
    7 CONTINUE                                                          INIT1170
      TWG2 = .3325                                                      INIT1180
C BLOWING T PROFILE                                                     INIT1190
      DO8K = 2,NETA                                                     INIT1200
      TP = TG2(K) +(T(1)- TWG2)                                         INIT1210
      T(K) = TP -(T(1)- TWG2) * ETA(K)                                  INIT1220
    8 CONTINUE                                                          INIT1230
      GO TO 11                                                          INIT1240
    9 CONTINUE                                                          INIT1250
      WRITE(6,1C1)                                                      INIT1260
      DO 1C K=2,NETA                                                    INIT1270
      TP = T(K) +T(1) -TWCLD                                            INIT1280
      T(K) = TP -(T(1)-TWCLD)*ETA(K)                                    INIT1290
      WRITE(6,1CC) T(K),ETA(K)                                          INIT1300
 10   CONTINUE                                                          INIT1310
 11   CONTINUE                                                          INIT1320
C                                                                       INIT1330
C  **  INITIALIZE SHOCK LAYER PARAMETERS FOR VARIABLE STEP SIZE         INIT1340
      DO 810 I=NETA,60                                                  INIT1350
      ETA(I)=1.C                                                        INIT1360
      T(I) = 1.0                                                        INIT1370
      TOLD(I) = 1.0                                                     INIT1380
      E(I) = C.C                                                        INIT1390
      PI(I) = PC                                                        INIT1400
      MU(I)=1.0                                                         INIT1410
      CP(I) = CP(NETA)                                                  INIT1420
      AK(I) = AK(NETA)                                                  INIT1430
      V(I) = VD                                                         INIT1440
```

```
      F(I) = FD
      FC(I)=FD
      DO 810 J=1,NSP
      C(J,I) = C(J,NETA)
      HS(J,I)=1.0
  810 CONTINUE
 1000 CONTINUE
C
      IF(RVW.LE.0.0) GO TO 24
      DO221I=1,NSP
      C(I,1) = CWALL(I)
  221 CONTINUE
   24 CONTINUE
C-----CALCULATE AMW(N)
      WAMW = 0.0
C
      DO 25 J=1,NSP
   25 WAMW = WAMW +CWALL(J)/SMW(J)
      WAMW = 1./WAMW
   26 AMW(1)= WAMW
C
C-----FLOAT AA(I,J) MATRIX....
C
      DO30I=1,NSP
      DO30J=1,NE
   30 AA(I,J)=IA(I,J)
C
      IF(ITYPE.EQ. 0) CALL RADIN
C
C
C SET UP AMW ARRAY FOR ABLATION PRODUCTS
      IF(IEM.LT.IAB) GO TO 51
      NFF = NETA -10
      CALL CHEMEQ(1,NFF)
      DO 50 I=1,NFF
      DO 49 J=1,NSP
```

```
49    C(J,I) = 1.0E-20
      AT(I) = T(I)
50    AAMW(I) = AMW(I)
51    CONTINUE
      N=2
 60   DO 62 I=N,NFF
      PRCT = ABS((AT(I)-AT(I-1))/AT(I-1))
      IF(PRCT.LT. .008) GO TO 64
 62   CONTINUE
      GO TO 68
 64   DO 66 J=I,NFF
      AAMW(J) = AAMW(J+1)
 66   AT(J) = AT(J+1)
      NFF = NFF-1
      N=I
      GO TO 60
 68   CONTINUE
C
      DTILS = .01
      IF(IDEBUG .EQ. 0) RETURN
      WRITE(6,4000) VD,DLD,PD
      WRITE(6,4000) DELTA,DTIL,RZB,RE
 4000 FORMAT(1H0,6E15.6)
 203  FORMAT(6E12.0)
  100 FORMAT(1X,9E14.6)
 101  FORMAT(7X,'T',13X,'ETA')
      RETURN
      END
```

```
      SUBROUTINE MONTM
C
C -----THIS SUBRCUTINE SCLVES THE MOMENTUM EQUATION AS A
C      SECCND ORDER EQUATICN AND A FIRST CRDER EQUATION -----
C
      COMMON /CONV/ FPRCT,THRCT,DCAMP,TCAMP,PDTIL
      COMMON /DEL/ DELTA,DTIL,DTILS
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /MAIN/KEEP,MAXE,MAXN,MAXD,IDEBUG,MCONV,ECONV,DCONV,LT,IAB
      COMMON /NON/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/PRCP1/PI(60),RHO(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMON/PROP2/  MU(60),RM(60), AK(60)
      COMMON/PROP3/CPS(20,60),HS(20,60),CP (60),HM(60)
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON /RP/ DUD,DPHI,TD,RZB,PD,HD,HTOTAL
      COMMON/VECTOR/ CA(60),CB(60),CC(60),B(60)
      COMMON /VEL/ F(60),FC(60),Z(60),V(60)
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON /YL/ETA(60),YOND(60)
      LOGICAL MCCNV,ECONV,DCONV
C
C----- INITIALIZED QUANTITIES -----
C
      MCONV = .FALSE.
      ITM = 1
      N = NETA -2
      L = NETA-1
      AA3 = RZB*(1.-RZB)*DPHI**2/DUD
      IF(IEM.GT.3) DTIL=.5*(DTIL+DTILS2)
C
C
C-----Z +A1*Z'+A2*Z=A3
C     COMPUTE A1,A2,A3
   14 CONTINUE
C----- BOUNDARY CONDITIONS -----
C
```

```
      RED = RE*CTIL
      RED2 = 2.*RED*DTIL*DUD
      DTIL2 = DTIL*DTIL
      FD = RZB/(2.*DUD*DTIL)
      FW = -RVW*FD
      F(1) = FW
      B(L) = 1./DTIL
      ITER = 1
   15 CONTINUE
      II = 1
      DO 20 I=1,N
      DET=ETA(I+1)-ETA(I)
      DETN=ETA(I+2)-ETA(I+1)
      D1   =   DETN*(DETN+DET)
      D2   =   DETN*DET
      D3   =   DET*(DETN+DET)
      RMP = DET*RM(I+2)/D1 +(DETN-DET)*RM(I+1)/D2 -DETN*RM(I)/D3
      A1 = (RED2*F(I+1) +RMP)/RM(I+1)
      A2 = -RED2*DTIL*Z(I)/RM(I+1)
      A3 = -2.*RED*( AA3/(RHO(I+1)*RM(I+1))
     1              +DTIL2  *DUD*Z(I)**2/(2.*RM(I+1)) )
C
C-----CA*Z(N-1)+CB*Z(N)+CC*Z(N+1)=B
C      COMPUTE CA,CB,CC
      CA(II) =(2.-A1*DETN)/D3
      CB(I)=A1*(DETN-DET)/D2-2./D2+A2
      CC(I)=(2.+A1*DET)/D1
      B(I)=A3
      II = I
   20 CONTINUE
      B(N)=B(N)-CC(N)/DTIL
C
      CALL TRID (N)
C
C-----INTEGRATE FIRST ORDER EQUATION-----
      FC(1)=FW
```

```
      SUM=FW+ (B(1)+FW)*(ETA(2)-ETA(1))*DTIL/2.
      FC(2)=SUM
      DO 30 K=3,NETA
      SUM=SUM+DTIL*(B(K-1)+B(K-2))*(ETA(K) -ETA(K-1))/2.
   30 FC(K) = SUM
C
C-----CHECK FOR CONVERGENCE
C
      DO 40 K=2,NETA
      PRCT=ABS((FC(K)-F(K))/F(K))
      IF (PRCT.GT.FPRCT) GO TO 50
   40 CONTINUE
      GO TO 90
   50 CONTINUE
      ITER=ITER+1
      DO 60 K=1,NETA
   60 F(K)=FC(K)
      DO 65I=1,N
   65 Z(I)=B(I)
      IF(ITER.GE.MAXM ) GO TO 90
      GO TO 15
   90 CONTINUE
C
C----- COMPUTE NEW DTIL -----
C
      DTILC = (FD-FW)*DTIL/(F(NETA)-FW)
      PRCT = ABS((DTIL-DTILC)/DTIL)
      IF(ITM.GT.MAXM) GO TO 160
      ITM = ITM +1
      IF(PRCT.LE.PDTIL) GO TO 150
      DTIL = DTIL +DDAMP*(DTILC-DTIL)
      GO TO 14
  150 CONTINUE
      DTIL = DTIL+ DDAMP*(DTILC -DTIL)
      NCONV = .TRUE.
C
```

```
C CHECK MOMENTUM-ENERGY CONVERGENCE
      PRCT = ABS((DTIL-DTILS)/DTILS)
      IF(PRCT.LE.PDTIL) DCONV = .TRUE.
 160  CONTINUE
C
      DO 170 K=1,NETA
 170  V(K) = -FC(K)*DTIL*2./RHO(K)
      DTILS2 = DTILS
C DEBUG OUTPUT
      IF(IDEBUG.EQ. 0) RETURN
      WRITE(6,102) ITER,ITM
      WRITE(6,100) DTIL,DTILC
      WRITE (6,101)
      DO 120 K=1,NETA
      VS=-FC(K)*DTIL*UINF*2./RHO(K)
      WRITE(6,100) ETA(K),F(K),FC(K),  RHO(K),RM(K),VS ,V(K)
  120 CONTINUE
      WRITE(6,103)
      DO 121 I=1,N
      U=B(I)*DTIL
      WRITE(6,100) ETA(I+1),Z(I),B(I),U
  121 CONTINUE
  100 FORMAT(1X,9E14.6)
 101  FORMAT(6X,'ETA',12X,'F',12X,'FC',12X,'RHO',12X,'RM',12X,'VS',12X,
     1 'V')
 102  FORMAT(10X,2I3/)
 103  FORMAT(6X,'ETA',13X,'Z',13X,'B',12X,2HF')
      RETURN
      END
```

```
      SUBROUTINE ERROR  ( N )
C
      IF(N .EQ. 1 ) WRITE(6,1 )
C
      IF(N .EQ. 2 ) WRITE(6,2 )
C
      IF(N .EQ. 3) WRITE(6,3)
C
C
      RETURN
C
    1 FORMAT(36H1 MOMENTUM EQUATION DID NOT CONVERGE      )
    2 FORMAT(34H1 ENERGY EQUATION DID NOT CONVERGE      )
    3 FORMAT(54H MOMENTUM AND ENERGY FAILED TO CONVERGE SIMULTANEOUSLY )
      END
```

```
      SUBROUTINE STPSZE
C
C     **  ROUTINE TO ADJUST STEP SIZE AS NEEDED
C         TO MAINTAIN ACCURACY   **
C
C
      COMMON /DEL/ DELTA,DTIL,DTILS
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /MAIN/KEEP,MAXE,MAXM,MAXD,ICEBUG,MCCNV,ECONV,DCONV,LT,IAB
      COMMON/PRCP1/PI(60),RHC(60),G (60),AMW(60),C (20,60),EC(5,60)
      COMMON/PRCP2/  MU(60),RM(60), AK(60)
      COMMON/PROP3/CPS(20,60),HS(20,60),CP (60),HM(60)
      COMMON /CLD/ TCLD(60),EOLD(60)
      COMMON /RH/ DUD,DPHI,ID,RZB,PC,HD,FTOTAL
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON /VEL/ F(60),FC(60),Z(60),V(60)
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON /YL/ETA(60),YCNC(60)
      IF(ICEBUG.GE.1) WRITE(6,100) IEM
  100 FORMAT(1X,' A STEP SIZE ADJUSTMENT WAS MADE AT ITERATION NO.',I3)
C
      N=2
    1 CONTINUE
      I2=2
      IF(NETA.GE. 59) GO TO 5
C
      DO 2 I=N,NETA
      L=I
      CHECK = ABS(G(I)-G(I-1) )
      IF(CHECK .GT. .05) GO TO 3
    2 CONTINUE
C
      GO TO 5
C
    3 CONTINUE
      M = NETA - L + 1
```

```
C
      DO 4 I=1,N
      K = NETA - I + 1
      G(K+1) = G(K)
      F(K+1) =F(K)
      RHO(K+1) = RHO(K)
      RM (K+1) = RM (K)
      TOLD(K+1) = TOLD(K)
      IF(IRAD.EQ.3) ECLD(K+1) = ECLD(K)
      IF(IRAD.EQ. 3) E(K+1) = E(K)
      ETA(K+1) = ETA(K)
    4 CONTINUE
C
      G(L) = (G(L-1) + G(L+1) ) / 2.0
      F(L) = (F(L-1)+F(L+1))/2.
      RHO(L) = (RHO(L-1) +RHO(L+1))/2.
      RM (L) = (RM (L-1) +RM (L+1))/2.
      TOLD(L) = (TOLD(L-1)+TOLD(L+1))/2.0
      IF(IRAD.EQ.3) ECLD(L) =(ECLD(L-1)+ECLD(L+1))/2.0
      IF(IRAD.EQ. 3) E(L) =(E(L-1)+ E(L+1))/2.0
      ETA(L) = (ETA(L-1) + ETA(L+1) )/2.0
      NETA = NETA + 1
      N=L
C
      IF( NETA .LT. 59) GO TO 1
C
    5 CONTINUE
C
      IF(I2 .GE. NETA) GO TO 10
      DO 6 I=I2,NETA,2
      L=I
      IF (L.EQ.NETA) GO TO 6
      IF(ETA(I).EQ. 0.98) GO TO 6
      CHECK =ABS(G(I+1) - G(I-1) )
      IF(CHECK .LT. 0.005) GO TO 7
    6 CONTINUE
```

```
C                                                             STPS 730
                                                              STPS 740
      GO TO 10                                                STPS 750
 7    CONTINUE                                                STPS 760
      I2=L+1                                                  STPS 770
      IF(ETA(L+1)-ETA(L-1).GT. .04) GO TC 5                   STPS 780
C                                                             STPS 790
      DO 8 I=L.NETA                                           STPS 800
      G(I) = G(I+1)                                           STPS 810
      F(I) = F(I+1)                                           STPS 820
      RHC(I) = RHC(I+1)                                       STPS 830
      RM (I) = RM (I+1)                                       STPS 840
      IOLD(I) = TOLD(I+1)                                     STPS 850
      IF(IRAD.EQ.3) EOLD(I) = EOLD(I+1)                       STPS 860
      IF(IRAD.EQ. 3) E(I) =E(I+1)                             STPS 870
      ETA(I)=ETA(I+1)                                         STPS 880
 8    CONTINUE                                                STPS 890
C                                                             STPS 900
      NETA=NETA-1                                             STPS 910
      IF (NETA .GT. 1) GO TU 5                                STPS 920
C                                                             STPS 930
 10   CONTINUE                                                STPS 940
      NN = NETA-2                                             STPS 950
      DO 20 I=1.NN                                            STPS 960
      Z(I) = ETA(I+1)/DTIL                                    STPS 970
 20   CONTINUE                                                STPS 980
      RETURN                                                  STPS 990
      END
```

```
      SUBROUTINE ENERGY
C
C-----THIS SUBRCUTINE SOLVES THE ENERGY EQUATION
C     IN A GLOBALLY IMPLICIT MANNER---------
C
      COMMON /CCNV/ FPRCT,TPRCT,DCAMP,TCAMP,PDTIL
      COMMON /DEL/ DELTA,DTIL,DTILS
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /MAIN/KEEP,MAXE,MAXM,MAXD,IDEBUG,MCONV,ECONV,DCONV,LT,IAB
      COMMON /NCN/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/NUMBER/NSP,NNS,NE,NC
      COMMON/PROP1/P1(60),RHO(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMON/PROP2/  MU(60),RM(60), AK(60)
      COMMON/PROP3/CPS(20,60),HS(20,60),CP (60),HM(60)
      COMMON /OLD/ TOLD(60),EOLD(60)
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON /RH/ DUC,DPHI,TD,RZE,PC,HD,HTOTAL
      COMMON/SP2/BR,S(20),CSHOCK(5)
      COMMON/VECTOR/ CA(60),CB(60),CC(60),B(60)
      COMMON /VEL/ F(60),FC(60),Z(60),V(60)
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON /YL/ETA(60),YOND(60)
      REAL  MU,MUDZ
      LOGICAL MCONV,ECCNV,DCONV
C
C-----INITIALIZED QUANTITIES-----
C
      ECONV = .FALSE.
      DTILN = DTIL
      IF(IEM.GE. 2) DTIL= DTILN+.4*(DTILS -DTILN)
      DTILS = DTILN
      N=NETA-2
      ITER = 0
      NF = 0
      EPRCT = .7
      DO 1 I=1,NETA
```

```
1     EOLD(I) = E(I)
      DO 3 I=1,NETA
3     TOLD(I) = T(I)
      DO 5 I=1,NETA
      IF(V(I).LT.0.0) GO TO 6
5     NF = NF +1
6     CONTINUE
      KODE = 1
      IF(IEM.GT.1) GO TC 7
      IF(ITYPE.NE.0.OR.IRAD.NE.3) GC TO 7
4     CALL GAS(KODE)
      IF(IEM.LT.IAB) GO TC 7
      IF(RVW.LE.0.0) GO TC 7
      CALL CHEMEQ(1,NF)
      CALL PRCPRT(NSP,1,NF)
7     CONTINUE
C
      IF(IRAD.EQ.3.AND .ITYPE.EQ.1) CALL EFLUX
      IF(IRAD.EQ.3. AND.ITYPE.EQ. 0) CALL LRAD
      IF(IEM.EQ.1) GO TC 9
      DO 8 I=1,NETA
8     E(I) = E(I)
9     CONTINUE
C
   10 CONTINUE
C
      NS = NSP
      CALL GAS (KODE)
      IF(IEM.LT.IAB)GO TC 11
      IF(RVW.LE.0.0) GO TO 11
      CALL CAMW(1,NF)
      CALL PRCPRT(NSP,1,NF)
11    CONTINUE
C
C-----I''+A1*T'=A2
C     COMPUTE A1 AND A2
```

```
C
      II = 1
      DO 20 I=1,N
      DET=ETA(I+1)-ETA(I)
      DETN=ETA(I+2)-ETA(I+1)
      C1= DET/(DETN*(DETN+DET))
      C2=(DETN-DET)/(DETN*DET)
      C3=DETN/(DET*(DETN+DET))
      COEF=DTIL/(2.*RHO(I+1)*AK(I+1))
C
C-----A1-------
C
      TARM1=RHO(I+1)*V(I+1)*CP(I+1)
      TARM2=0.0
      TARM3=C1*RHO(I+2)*AK(I+2)+C2*RHO(I+1)*AK(I+1)
     1     -C3*RHO(I)*AK(I)
      A1=-COEF*(TARM1+TARM2-TARM3)
C
C-----A2------
C
      TERM1 = 0.0
      TERM2=2.*V(I+1)*(C1*V(I+2)+C2*V(I+1)-C3*V(I))
      TERM3=0.0
      A2=COEF*(RHO(I+1)*V(I+1)*(TERM1+TERM2)
     1          +TERM3+2.*DTIL*E(I+1)/RHO(I+1) )
C
C-----CA*T(N-1)+CB*T(N)+CC*T(N+1)=B
C
      CA(II) = C3*(-A1+2./DETN)
      CB(I) =C2* A1 -2./(DETN*DET)
      CC(I) = C1*(A1+2./DET)
      IF (I.EQ.1) BC=CA(1)*T(1)
      E(I)=A2-BC
      BC=0.0
      II = I
   20 CONTINUE
```

```
      B(N)=A2-CC(N)                                                     ENER1090
C                                                                       ENER1100
      CALL TRID (N)                                                     ENER1110
C                                                                       ENER1120
C-----CHECK FOR CONVERGENCE                                             ENER1130
C                                                                       ENER1140
      DO 30 I=1,N                                                       ENER1150
      PRCT=ABS((B(I)-T(I+1))/T(I+1))                                    ENER1160
      IF (PRCT.GT.TPRCT) GO TO 40                                       ENER1170
   30 CONTINUE                                                          ENER1180
      GO TO 90                                                          ENER1190
   40 ITER=ITER+1                                                       ENER1200
      DO 50 I=1,N                                                       ENER1210
      II=I+1                                                            ENER1220
      T(II) = T(II) +TDAMP*(B(I)-T(II))                                 ENER1230
      IF(T(II).GT.1.0) T(II) = .99999                                   ENER1240
      IF(T(II).LT.T(1)) T(II)=1.000001*T(1)                             ENER1250
   50 CONTINUE                                                          ENER1260
      IF(ITER.GE.MAXE ) GOTO 90                                         ENER1270
      GO TO 10                                                          ENER1280
   90 CONTINUE                                                          ENER1290
      IF(ITER.LT.MAXE) ECONV=.TRUE.                                     ENER1300
      IF(IEM.EQ.2.OR.IEM.EQ.4) CALL STPSZE                              ENER1310
      IF(IEM.GT.IAB.AND. IEM.LT.IAB+4) CALL STPSZE                      ENER1320
C                                                                       ENER1330
      TMCH = .04                                                        ENER1340
      DO 91 I=1,N                                                       ENER1350
      II = I+1                                                          ENER1360
      DO 92 J=1,NSP                                                     ENER1370
 92   C(J,II) = 1.E-20                                                  ENER1380
      T(II) = T(II) +.4*(TOLD(II) -T(II))                               ENER1390
      PRCT = (T(II)-TOLD(II))/TOLD(II)                                  ENER1400
      IF(ABS(PRCT).GT.TMCH) T(II)=TOLD(II)+TMCH*PRCT*TOLD(II)/ABS(PRCT) ENER1410
 91   CONTINUE                                                          ENER1420
      CALL GAS(KODE)                                                    ENER1430
      IF(IEM.LT.IAB) GO TO 93                                           ENER1440
```

```
      IF(RVW.LE.0.0) GO TC 93                                           ENER1450
      CALL CHEMEC(1,NF)                                                 ENER1460
      CALL PROPRT (NSP,1,NF)                                            ENER1470
 93   CONTINUE                                                          ENER1480
      DTIL = DTILN                                                      ENER1490
C DEBUG OUTPUT                                                          ENER1500
      IF(IDEBUG.EQ. 0) RETURN                                           ENER1510
      WRITE(6,102) ITER                                                 ENER1520
      N=NETA-2                                                          ENER1530
      DO 95 I=1,N                                                       ENER1540
      K= I+1                                                            ENER1550
      WRITE(6,100) ETA(K),T(K),B(I),E(K)                                ENER1560
  95  CONTINUE                                                          ENER1570
 100  FORMAT(1X,9E14.6)                                                 ENER1580
 102  FORMAT(1X,'NO. OF ENERGY ITER.=',I3/,6X,'ETA',14X,'T',14X,'B',    ENER1590
     1   14X,'E')                                                       ENER1600
      RETURN                                                            ENER1610
      END                                                               ENER1620
```

```
      DIMENSION  XKT(60),           DQ(60)
C
C **   BAND AVERAGE ABSORPTION CROSS SECTION (EQ.A2)   **
C
      SIGMA(ZH,ZA,ZB,ZG)=  ((5.0E+03*T1*ZG*ZKZ)/BE) * (EXP(ZDL/T1)
     1                     *ZH*(ZA+ZB* (ZH**2)/3.0) +
     2                     T1 * (ZA+2.0*ZB*T12) -T1*EXP((ZH-ZHVP)/T1)
     3                     *(ZA+ZB*(ZHVP-ZH)**2) -T1*EXP((ZH-ZHVP)/T1)
     4                     *2.0*ZB*T1*(ZHVP-ZH+T1))
      SIGMA2(ZH,ZG,ZE,ZY)=7.26E-16*T1*ZG*EXP((-ZE+ZY+ZDL)/T1)/ZH**3
      GAMMA(ZX)=(1.0+(1.5707963*ZX)**1.25)**(-0.4)
      XLAMB(ZX)=(1.0+ZX*EXP(-ZX))/SQRT(1.0+6.283185 *ZX)
C
C **   W(GROUP)/D CORRELATION (EQ.88)   **
C
      PHI1(ZX)=(ATAN(1.570796 *ZX)/1.570796 )
C
C **   FLUX DIVERGENCE OVERLAPPING FUNCTION (EQ.92)   **
C
      PHI2(ZX)=EXP(-ZX)
C
      DO 400  I=1,NES
  400 T(I)= T(I)*TD
      ZHVP=5.0
      YI=0.0
      CONVER = 3.10375E+23 *R   (I) *RCZ
      SNDE(NES) = CONVER * C( 7,NES)/SMW(7)
      XNE=SNDE(NES)
      FNE=(4.71E-6 * XNE**(2.0/7.0))/((T(NES)/11606.)**(1.0/7.0))
      ZDL=AMIN1(0.20,FNE)
C
C **   DEBUG PRINT   **
C
      IF (IDG.NE.0) CALL BUGPR (1)
      DELTA=W(1) * XL * 30.48006
      CALL BUGPR (2)
```

```
6001 CONTINUE
     DO 91 L=1.NES
     XKT(L)=T(L)/11606.
     T1=XKT(L)
     CALL SND(L)
C
C **   PARTITION FUNCTIONS FOR H. C. N. C   **
C
  94 IF(T(L).GT.15000.) GO TO 6
C
C **   LOW  TEMPERATURE  **
C
     SUMH=2.0
     SUMC=9.0   +   5.0 * EXP(-1.264/T1) + EXP(-2.684/T1) +
    1               5.0 * EXP(-4.183/T1)
     SUMN=4.0 + 10.0 *EXP(-2.384/T1) + 6.0 *EXP(-3.576/T1)
     SUMO= 9.0 + 5.0 * EXP(-1.975/T1)
     GO TO 7
C
C **   HIGH TEMPERATURE   **
C
   6 SUMH=2.0
     SUMC=2.71818  +  6.40677 * T(L)/1.0E4 -0.45466 * (T(L)/1.0E4)**2
     SUMN=5.938216 - 0.225593 * T(L)/1.0E3 + 0.015408 * (T(L)/1.0E3)**2
     SUMO=11.79563 -0.317964 * T(L)/1.0E3 + 0.013765 * (T(L)/1.0E3)**2
   7 CONTINUE
     T12=T1**2
     GH = 6.4994
     DO 5 K=1.12
     GF=FHVC(K)/T1
     GHM=GH
     GH=EXP(-GF)  *GF  *  (GF**2 + 3.0 *GF  +6.0  + 6.0/GF)
C
C **   PLANK MEAN ABSORPTION COEFFICIENT FOR BAND INTERVALS (EQ.A3)  **
C
     BEEC(K.L)=5.04E3  *  (T12**2)  *  (GHM-GH)
```

```
      BE=BEEC(K,L)                                                      TRAN1090
C                                                                       TRAN1100
C **   ABSORPTION CROSS SECTIONS  **                                    TRAN1110
C      SOECIES --                                                       TRAN1120
C                    N          N2          CO                          TRAN1130
C                    O          O2                                      TRAN1140
C                    C          C2          C2H                         TRAN1150
C                    H          H2          C3                          TRAN1160
C                                                                       TRAN1170
      SGH=0.                                                            TRAN1180
      SGN=0.                                                            TRAN1190
      SGC=0.                                                            TRAN1200
      SGO=0.                                                            TRAN1210
      SGCO=0.                                                           TRAN1220
      SGC2=0.                                                           TRAN1230
      SGO2=0.                                                           TRAN1240
      SGN2=0.                                                           TRAN1250
      SGH2=0.                                                           TRAN1260
      SGC3=0.                                                           TRAN1270
      SGC2H = 0.0                                                       TRAN1280
      GO TO (581,582,583,584,585,586,587,588,589,590,591,592),K         TRAN1290
  581 SGH=SIGMA(2.4,1.0,0.0,1.0)  *  EXP(-13.56/T1)                     TRAN1300
      SGC=SIGMA(3.78,  0.3,   0.0488,  1.33)  * EXP(-11.26/T1)          TRAN1310
      SGN=SIGMA(4.22,  0.24,  0.0426,  4.5) * EXP(-14.54/T1)            TRAN1320
      SGO=SIGMA(4.22,  0.24,  0.0426,   .8888889)  * EXP(-13.61/T1)     TRAN1330
      GO TO 38                                                          TRAN1340
  582 ZZHV=5.5                                                          TRAN1350
      SGC2=8.0E-18 * EXP(-0.5/T1)   +   3.0E-18                         TRAN1360
      SGC3=4.0E-18                                                      TRAN1370
  593 CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1380
      SGC=SIGMA2(ZZHV, 1.33,  11.26,  3.78) * ZZC + SGC                 TRAN1390
      SGN=SIGMA2 (ZZHV,4.50,  14.54,  4.22) * ZZN                       TRAN1400
  594 SGO=SIGMA2 (ZZHV, .889,  13.61,  4.22) * ZZO                      TRAN1410
  595 SGH=SIGMA2 (ZZHV, 1.00,  13.56,  2.40)                            TRAN1420
      GO TO 38                                                          TRAN1430
  583 ZZHV=6.5                                                          TRAN1440
```

```
      SGC2=1.0E-18                                                      TRAN1450
      SGCO=3.0E-18 * EXP(-0.7/T1)                                       TRAN1460
      GO TO 593                                                         TRAN1470
  584 ZZHV=7.5                                                          TRAN1480
      SGC=5.0E-17  * EXP(-4.18/T1)/SUMC                                 TRAN1490
      SGCO=1.9E-17  * EXP(-0.5/T1)                                      TRAN1500
      SGO2=6.0E-19                                                      TRAN1510
      SGC2H = 1.3E-18                                                   TRAN1520
      GO TO 593                                                         TRAN1530
  585 ZZHV=8.5                                                          TRAN1540
      SGC=5.0E-17 *EXP(-4.18/T1)/SUMC  +                                TRAN1550
     1    2.2E-17* EXP(-2.68/T1)/SUMC                                   TRAN1560
      SGCO=2.5E-17                                                      TRAN1570
      SGO2=2.0E-19                                                      TRAN1580
      SGC2H = 8.5E-19                                                   TRAN1590
      GO TO 593                                                         TRAN1600
  586 ZZHV=9.5                                                          TRAN1610
      SGC=5.0E-17 * EXP(-4.18/T1)/SUMC  +                               TRAN1620
     1    2.2E-17 * EXP(-2.68/T1)/SUMC                                  TRAN1630
      SGCO=5.0E-18                                                      TRAN1640
      SGO2=1.0E-18                                                      TRAN1650
      GO TO 593                                                         TRAN1660
  587 SGN=3.2E-18 *T1 *EXP(-10.2/T1)/SUMN                               TRAN1670
      SGO2=6.0E-19                                                      TRAN1680
      ZZHV=10.4                                                         TRAN1690
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1700
  596 SGC=(8.5E-17 *EXP(-1.26/T1)  +  2.2E-17 * EXP(-2.75/T1)           TRAN1710
     1    +  5.0E-17 * EXP(-4.18/T1))/SUMC                              TRAN1720
      GO TO 594                                                         TRAN1730
  588 ZZHV=10.9                                                         TRAN1740
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1750
      SGN=(5.16E-17  *EXP(-3.50/T1))/SUMN                               TRAN1760
      GO TO 596                                                         TRAN1770
  589 ZZHV=11.6                                                         TRAN1780
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1790
      SGN2=1.0E-18                                                      TRAN1800
```

```
      SGN=(5.16E-17 *  EXP(-3.50))/SUMN
  598 SGC=(9.9E-17  +  8.5E-17 * EXP(-1.26/T1)  +2.2E-17 * EXP(-2.75/T1)
     1     +  5.0E-17 * EXP(-4.18/T1))/SUMC
      IF (K.LT.11) GO TO 594
      GO TO 38
  590 ZZHV=12.7
      CALL ZHV  (ZZHV.ZZC.ZZN.ZZI.ZZC)
      SGN2=2.0E-18
      SGH2 = 2.7E-17
  599 SGN=(6.4E-17 * EXP(-2.30/T1)   +   5.16E-17 * EXP(-3.50/T1))/SUMN
     1     +  SGN
      GO TO 598
  591 SGH=1.18E-17/SUMH
      SGO=3.6E-17/SUMO
      SGN2=1.0E-17
      SGH2 = 2.7E-17
      GO TO 599
  592 SGN=3.6E-17/SUMN
      SGN2=1.0E-18
      GO TO 599
   38 CONTINUE
      FMUC(K.L)= SNCH(L)*SGH + SNCC(L)*SGC + SNDN(L)*SGN + SNDO(L)*SGO
     1           + XNOL *     (SNDN2(L)*SGN2 + SNDO2(L)*SGO2 +
     2           SNDC2(L)*SGC2 + SNCH2(L)*SGH2 + SNDCO(L)*SGCO +
     3           SNDC3(L)*SGC3 +SNCC2H(L)*SGC2H )
      IF (L.GT.1) GO TO 8
      TAUC(K.L)=0.
      GO TO 5
    8 TAUC(K.L)=TAUC(K.L-1)+(YD(L)-YD(L-1))*
     1     (FMUC(K.L-1)+FMUC(K.L)) * DELTA
    5 CONTINUE
      IF (LINES.EQ.0) GO TO 91
C
C **   FRACTIONAL POPULATION STATES FOR H. N. O. C  **
C
      CALL ZP (T1.SUMN.SUMO.SUMH.SUMC)
```

```
C **   CALCULATICN OF PARAMETERS FOR 9 LINE GROUPES  **                TRAN2170
C      WN -- NUMBER CF LINES                                            TRAN2180
C      FG -- EFFECTIVE F-NUMBER                                         TRAN2190
C      GP -- EFFECTIVE HALF-WIDTH                                       TRAN2200
C                                                                       TRAN2210
C GROUP 1                                                               TRAN2220
      FG(1,2)=(1.C2 * ZPC(5)  +  .795 * ZPC(6)  +  0.114 * ZPC(7))      TRAN2230
     1  /WN(1,2)                                                        TRAN2240
      GP(1,2)=(8.16E-11 * SCRT(ZPC(5))  +  1.25E-10 * SQRT(ZPC(6))      TRAN2250
     1     +2.55E-1C * SCRT(ZPC(7)))**2 /(FC(1,2)* WN(1,2)**2)          TRAN2260
      FG(1,3)=(1.C4C * ZPN(4)  +  1.29 * ZPN(5)  +  0.00 *ZPN(6))       TRAN2270
     1        /WN(1,3)                                                  TRAN2280
      GP(1,3)=(6.65E-11 * SCRT(ZPN(4))  +  1.71E-10 * SQRT(ZPN(5))      TRAN2290
     1     +  C.CCE-1C * SCRT(ZPN(6)))**2/(FG(1,3) * WN(1,3)**2)        TRAN2300
      FG(1,4)=(1.CC * ZPC(5)  +  .978 * ZPC(6))/WN(1,4)                 TRAN2310
      GP(1,4)=(3.90E-11 * SCRT(ZPC(5))  +  9.68E-11 * SQRT(ZPO(6)))**2  TRAN2320
     1        /(FG(1,4) * WN(1,4)**2)                                   TRAN2330
      FMUL(1,L)=FMUC(1,L)                                               TRAN2340
C GROUP 2                                                               TRAN2350
      FG(2,1)=0.805 * ZPH(2)/WN(2,1)                                    TRAN2360
      GP(2,1)=2.37E-10 * 2.37E-10 * ZPH(2)/(FG(2,1) * WN(2,1)**2)       TRAN2370
      FG(2,2)=(C.COE-2 * ZPC(5)  +  6.71E-2 * ZPC(6))/WN(2,2)           TRAN2380
      GP(2,2)=(C.COE-12 * SQRT(ZPC(5))  +  7.15E-11 * SQRT(ZPC(6)))**2  TRAN2390
     1        /(FG(2,2) * WN(2,2)**2)                                   TRAN2400
      FG(2,3)=(C.C47* ZPN(4)  +  2.85E-2 * ZPN(5))/WN(2,3)              TRAN2410
      GP(2,3)=(1.11E-10 * SQRT(ZPN(4))  +  6.07E-11 * SQRT(ZPN(5)))**2  TRAN2420
     1        /(FG(2,3) * WN(2,3)**2)                                   TRAN2430
      FG(2,4)=(.C217 * ZPC(4)  +  8.25E-2 * ZPO(5))/WN(2,4)             TRAN2440
      GP(2,4)=(2.61E-11 * SQRT(ZPC(4))  +  7.19E-11 * SQRT(ZPO(5)))**2  TRAN2450
     1  /(FG(2,4) * WN(2,4)**2)                                         TRAN2460
      FMUL(2,L)=FMUC(1,L)                                               TRAN2470
C  GROUP 3                                                              TRAN2480
      FG(3,2)=(7.29E-2 * ZPC(2)  +  6.76E-2 *ZPC(3))/WN(3,2)            TRAN2490
      GP(3,2)=(9.C8E-12 * SQRT(ZPC(2))  +  8.75E-12 * SQRT(ZPC(3)))**2  TRAN2500
     1        /(FG(3,2) * WN(3,2)**2)                                   TRAN2510
      FMUL(3,L)=FMUC(2,L)                                               TRAN2520
```

```
C   GROUP 4
      FG(4,2)=(1.05 * ZPC(1)   +   1.10E-2 *ZPC(2)   +   0.150 * ZPC(3))
     1        /WN(4,2)
      GP(4,2)=(9.57E-12 * SQRT(ZPC(1))   +   4.86E-12 * SQRT(ZPC(2))
     1        +  5.93E-10 * SQRT(ZPC(3)))**2/(FG(4,2) * WN(4,2)**2)
      FG(4,3)=( 7.40E-2   * ZPN(2)   +   6.34E-2 * ZPN(3))/WN(4,3)
      GP(4,3)=(8.22E-12 * SQRT(ZPN(2))   +   7.60E-12 * SQRT(ZPN(3)))**2
     1        /(FG(4,3) * WN(4,3)**2)
      FMUL(4,L)=FMUC(4,L)
C   GROUP 5
      FG(5,2)=(0.329 * ZPC(1)   +   0.118 * ZPC(2)   +   0.226 * ZPC(4))
     1        /WN(5,2)
      GP(5,2)=(3.65E-11 * SQRT(ZPC(1))   +   5.77E-10 * SQRT(ZPC(2))
     1        +  6.56E-11 *  SQRT(ZPC(4)))**2/(FG(5,2) * WN(5,2)**2)
      FG(5,3)=0.108 * ZPN(3)/WN(5,3)
      GP(5,3)=3.09E-11 * 3.09E-11 * ZPN(3)/(FG(5,3) * WN(5,3)**2)
      FG(5,4)=4.71E-2 * ZPO(1)/WN(5,4)
      GP(5,4)=5.08E-12 * 5.08E-12 * ZPO(1)/(FG(5,4) * WN(5,4)**2)
      FMUL(5,L)=FMUC(6,L)
C   GROUP 6
      FG(6,1)=0.416 * ZPH(1)/WN(6,1)
      GP(6,1)=3.02E-11 * 3.02E-11 * ZPH(1)/(FG(6,1)* WN(6,1)**2)
      FG(6,2)=8.65E-2 * ZPC(1)/WN(6,2)
      GP(6,2)=2.35E-10 * 2.35E-10 * ZPC(1)/(FG(6,2) * WN(6,2)**2)
      FG(6,3)=(0.184 * ZPN(1)   +  0.290 * ZPN(2)   +   8.52E-2 * ZPN(3))
     1        /WN(6,3)
      GP(6,3)=(1.07E-11 * SQRT (ZPN(1))   +   4.28E-11 * SQRT(ZPN(2))
     1        +  2.09E-10 * SQRT(ZPN(3)))**2/(FG(6,3) * WN(6,3)**2)
      FG(6,4)=(.120 * ZPC(2)   +   0.151 * ZPC(3))/WN(6,4)
      GP(6,4)=(8.85E-12 * SQRT(ZPC(2))   +   9.93E-12 * SQRT(ZPO(3)))**2
     1        /(FG(6,4) * WN(6,4)**2)
      FMUL(6,L)=FMUC(7,L)
C   GROUP  7
      FG(7,2)=(4.51E-2 * ZPC(1)   +   0.705 * ZPC(2))/WN(7,2)
      GP(7,2)=(6.07E-10 * SQRT(ZPC(1))   +   2.10E-10 * SQRT(ZPC(2)))**2
     1        /(FG(7,2) * WN(7,2)**2)
```

```
      FG(7,3)=(0.454 * ZPN(1)  +  9.66E-2 * ZPN(2)                      TRAN2890
     1       +  0.178 * ZPN(3))/WN(7,3)                                 TRAN2900
      GP(7,3)=(2.71E-12 * SQRT(ZPN(1))  +  2.34E-10 * SQRT(ZPN(2))      TRAN2910
     1       +  2.46E-11 * SQRT(ZPN(3)))**2/(FG(7,3)* WN(7,3)**2)       TRAN2920
      FG(7,4)=4.23E-2 * ZPO(3)/WN(7,4)                                  TRAN2930
      GP(7,4)=2.52E-11 * 2.52E-11 * ZPO(3)/(FG(7,4) * WN(7,4)**2)       TRAN2940
      FMUL(7,L)=FMUC(9,L)                                               TRAN2950
C   GROUP  8                                                            TRAN2960
      FG(8,1)=0.108 * ZPH(1)/WN(8,1)                                    TRAN2970
      GP(8,1)=1.32E-10  *  1.32E-10 * ZPH(1)                            TRAN2980
     1       /(FG(8,1) * WN(8,1)**2)                                    TRAN2990
      FG(8,2)=(0.379 * ZPC(1)  +  1.05 * ZPC(3))/WN(8,2)                TRAN3000
      GP(8,2)=(1.95E-11 * SQRT(ZPC(1))  +  1.27E-10 * SQRT(ZPC(3)))**2  TRAN3010
     1       /(FG(8,2) * WN(8,2)**2)                                    TRAN3020
      FG(8,3)=(0.155 * ZPN(1)  +  0.142*ZPN(2)  +  3.75E-2 * ZPN(3))    TRAN3030
     1       /WN(8,3)                                                   TRAN3040
      GP(8,3)=(2.98E-11 * SQRT(ZPN(1))  +  7.08E-11 * SQRT(ZPN(2))      TRAN3050
     1       +  1.33E-10 * SQRT(ZPN(3)))**2/(FG(8,3) * WN(8,3)**2)      TRAN3060
      FG(8,4)=(0.148 * ZPC(1)  +  8.61E-2*ZPO(2)                        TRAN3070
     1       +  9.33E-2 * ZPO(3))/WN(8,4)                               TRAN3080
      GP(8,4)=(1.97E-10 * SQRT(ZPC(1))  +  1.80E-11 * SQRT(ZPO(2))      TRAN3090
     1       +  8.13E-11 * SQRT(ZPO(3)))**2/(FG(8,4) * WN(8,4)**2)      TRAN3100
      FMUL(8,L)=FMUC(10,L)                                              TRAN3110
C   GROUP  9                                                            TRAN3120
      FG(9,2)=2.95 * ZPC(2)/WN(9,2)                                     TRAN3130
      GP(9,2)=5.85E-12 * 5.85E-12 * ZPC(2)/(FG(9,2) * WN(9,2)**2)       TRAN3140
      FG(9,3)=(0.224 * ZPN(1)  +  2.92E-2 * ZPN(2))/WN(9,3)             TRAN3150
      GP(9,3)=(3.41E-10 * SQRT(ZPN(1))  +  1.48E-10 * SQRT(ZPN(2)))**2  TRAN3160
     1       /(FG(9,3) * WN(9,3)**2)                                    TRAN3170
      FG(9,4)=(5.24E-2 * ZPO(1)  +  7.22E-2 * ZPO(2)                    TRAN3180
     1       +  6.04E-2 * ZPO(3))/WN(9,4)                               TRAN3190
      GP(9,4)=(5.76E-12 * SQRT(ZPC(1))  +  7.20E-11 * SQRT(ZPO(2))      TRAN3200
     1       +  8.05E-11 * SQRT(ZPO(3)))**2/(FG(9,4) * WN(9,4)**2)      TRAN3210
      FMUL(9,L)=FMUC(11,L)                                              TRAN3220
C                                                                       TRAN3230
C **   PLANCK FUNCTION   **                                             TRAN3240
```

```
C
      DO 9 J=1,NHVL
      BEEL(J,L)=5.04E3 * HVJ(J)**3 / (EXP(HVJ(J)/T1)  -  1.0)
C
C **   INDUCED EMISSION FACTOR (EQ 81)  **
C
      SSM(J,1,L)=1.10E-16*SNDH (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,1)
      SSM(J,2,L)=1.10E-16*SNDC (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,2)
      SSM(J,3,L)=1.10E-16*SNDN (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,3)
      SSM(J,4,L)=1.10E-16*SNDO (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,4)
      DO 10 M=1,4
      GGM(J,M,L)=GP(J,M) * SNDE(L)   * (T(L)/1.0E4)**0.25
     1          +  1.0E-6
      IF(L.GT.1) GO TO 11
      ETAM(J,M,1)=0.
      SBM (J,M,1)=0.
      GO TO 10
   11 ETAM(J,M,L)=ETAM(J,M,L-1)+  (YD(L)-YD(L-1))  +  SSM(J,M,L) * GGM(J,M,L))
     1          *(SSM(J,M,L-1) * GGM(J,M,L-1)
     2          * DELTA/3.14159265
      SBM(J,M,L)=SBM(J,M,L-1)  +  (YD(L)-YD(L-1))
     1          *  (SSM(J,M,L-1)+SSM(J,M,L)) * DELTA
   10 CONTINUE
      IF (L.GT.1) GO TO 12
      TAUL(J,1)=0.
      GO TO 9
   12 TAUL(J,L)=TAUL(J,L-1)  +  (YD(L)-YD(L-1))
     1          * (FMUL(J,L-1)+FMUL(J,L))  * DELTA
    9 CONTINUE
      IF (IDG.NE.99) GO TO 91
      CALL DUGPR (7)
C
   91 CONTINUE
      IEZ=IEZ+1
      EFZ(IEZ)=1.0
C
```

```
C **    CONTINUUM - CONTINUUM FLUX DIVERGENCE CALCULATION   **
C
      DO 300 K=1,IEZ
      DO 31 LK=1,NES
      I=LK
      NUT(K)=I
      IF (ABS(ETZ(K)-ETA(LK)) - 1.0E-5) 300,300,31
   31 CONTINUE
  300 CONTINUE
      DO 1612 J=1,9
      GCLP(J)=0.
      GLCP(J)=0.
      GLLP(J)=0.
      DO 1612 L=1,NES
      FM(J,L)=0.
 1612 FP(J,L)=0.
      DO 1613 L=1,IEZ
      GCL(L)=0.
      GLC(L)=0.
 1613 GLL(L)=0.
      DO 49 IYY=1,IEZ
      IY=NUT(IYY)
      DO 20 K=1,12
      FMC(K,IY)=0.
      FPC(K,IY)=0.
      IF (IY.EQ.1) GO TO 44
      DO 40 L=1,IY
C
C **    MINUS EMISSIVITY FUNCTION (EQ 47)   *
C
      EM(K,L)=1.0  -  EXP(TAUC(K,L)-TAUC(K,IY))
      IF (L.EQ.1) GO TO 40
C
C **    MINUS CONTINUUM FLUX (EQ 46)   **
C
      FMC(K,IY)=FMC(K,IY)  -  (EM(K,L)-EM(K,L-1))
```

```
     1          * (BEEC(K,L-1)+BEEC(K,L))/2.
   40 CONTINUE
   44 IF (IY.EQ.NES ) GC TO 41
      DO 42 L=IY,NES
C
C **    POSITIVE EMISSIVITY FUNCTICN (EQ 47)   **
C
      EP(K,L)=1.C  -  EXP(TAUC(K,IY)-TAUC(K,L))
      IF (L.EO.IY) GO TO 42
C
C **    POSITIVE EMISSIVITY CONTINUUM FLUX (EQ 46)   **
C
      FPC(K,IY)=FPC(K,IY)  +  (EP(K,L)-EP(K,L-1))
     1          * (BEEC(K,L-1)+BEEC(K,L))/2.
   42 CONTINUE
C
C **    POSITIVE EMISSIVITY CONTINUUM FLUXDIVERGENCE (EQ 51)   **
C
   41 GCCP(K)=6.2831853 * FMUC(K,IY) *
     1          (FMC(K,IY)  +  FPC(K,IY)   -   2.0* BEEC(K,IY))
      FMC(K,IY)=FMC(K,IY) * 3.14159265
      FPC(K,IY)=FFC(K,IY) * 3.14159265
   20 CONTINUE
C
C **    DEBUG PRINT   **
C
      IF (IDG.NE.99) GO TC 21
      CALL BUGPR (3)
   21 GCC(IYY)=C.
      DO 24 K=1,12
C
C **    LINE AND CROSS TERM FLUX DIVERGENCE CALCULATION   **
C
   24 GCC(IYY)=GCC(IYY)  +  GCCP(K)
      IF (LINES.EQ.0) GC TO 1614
C
```

```
C **    INTEGRATION FROM 1 TO IY   **
C
       IF (IY.EQ.1) GO TO 68
       DO 65 J=1,9
       DO 66 L=1,IY
       WIM=0.
       SUM1=0.
       SUM2=0.
       DO 67 M=1,4
       DIF=ETAM(J,M,IY)   -   ETAM(J,M,L)
       DIFSBM =         SBM(J,M,IY)-SBM(J,M,L)
       IF(ABS(DIFSBM).LT.1.E-10)   DIFSBM = 1.E-10
       BETAM=DIF / ( DIFSBM                      )  *  3.14159265
       IF (L.EQ.IY) BETAM=GGM(J,M,L)
       IF(ABS(DIF).GT.1.E-10)  GO TO 9001
       TM = 1.E-10
       GO TO 9002
 9001  CONTINUE
       TM=DIF/2.0/BETAM**2
 9002  RRM=DIF/2.0/GGM(J,M,IY)**2
       WWM=6.2831853 * WN(J,M) * BETAM * GAMMA(TM) * TM
       SUM1=SUM1   +   GAMMA(TM) * WN(J,M) * SSM(J,M,IY)
       SUM2=SUM2   +   XLAMB(RRM) * WN(J,M) * SSM(J,M,IY)
   67  WIM=WIM   +   WWM
       ALPHAM=WIM/DJ(J)
C
C **    OVERLAPPING LINE CALCULATIONS   **
C
C
C **    GROUP EQUIVALENT WIDTHS   (EQ.88)   **
C
       WMM(J,L)=DJ(J) * PHI1(ALPHAM) * EXP(TAUL(J,L)-TAUL(J,IY))
C
C **    GROUP GAMMA -- LINE TRANSPORT FUNCTION (EQ.92)   **
C
       GMM(J,L)=PHI2(ALPHAM) * SUM1
```

```
C                                                                       TRAN4690
C **   MINUS EMISSIVITY FUNCTION FOR LINES (EQ.47)   **                 TRAN4700
C                                                                       TRAN4710
      EEM(J,L)=1.0  -  EXP(TAUL(J,L)-TAUL(J,IY))                        TRAN4720
   66 XLMM(J,L)=PHI2(ALPHAM) * SUM2                                     TRAN4730
   65 CONTINUE                                                          TRAN4740
      IF (IDG.EQ.99) CALL BUGPR(1)                                      TRAN4750
      IF (IDG.EQ.99) CALL BUGPR (4)                                     TRAN4760
   68 IF (IY.EQ.NES) GO TO 72                                           TRAN4770
C                                                                       TRAN4780
C **   INTEGRATION FROM IY TO NES   **                                  TRAN4790
C                                                                       TRAN4800
      DO 69 J=1,9                                                       TRAN4810
      DO 70 L=IY,NES                                                    TRAN4820
      WIP=0.                                                            TRAN4830
      SUM1=0.                                                           TRAN4840
      SUM2=0.                                                           TRAN4850
      DO 71 M=1,4                                                       TRAN4860
      DIF=ETAM(J,M,L)  -  ETAM(J,M,IY)                                  TRAN4870
      DIFSUM =      SUM(J,M,L)-SUM(J,M,IY)                              TRAN4880
      IF(ABS(DIFSUM).LT.1.E-10)  DIFSUM = 1.E-10                        TRAN4890
      BETAP=DIF / ( DIFSUM                   )  *  3.14159265           TRAN4900
      IF (L.EQ.IY) BETAP=GGM(J,M,L)                                     TRAN4910
      IF(ABS(DIF).GT.1.E-10) GO TO 9003                                 TRAN4920
      TP = 1.E-10                                                       TRAN4930
      GO TO 9004                                                        TRAN4940
 9003 CONTINUE                                                          TRAN4950
      TP=DIF/2.0/BETAP**2                                               TRAN4960
 9004 RRP=DIF/2.0/GGM(J,M,IY)**2                                        TRAN4970
      WWP=6.2831853 * WN(J,M) * BETAP * GAMMA(TP) * TP                  TRAN4980
      SUM1=SUM1   +  GAMMA(TP) * WN(J,M) * SSM(J,M,IY)                  TRAN4990
      SUM2=SUM2   +  XLAMB(RRP) * WN(J,M) * SSM(J,M,IY)                 TRAN5000
   71 WIP=WIP+WWP                                                       TRAN5010
      ALPHAP=WIP/DJ(J)                                                  TRAN5020
      WPP(J,L)=DJ(J) * PHI1(ALPHAP) * EXP(TAUL(J,IY)-TAUL(J,L))         TRAN5030
      GPP(J,L)=PHI2(ALPHAP) * SUM1                                      TRAN5040
```

```
C
C **   POSITIVE EMISSIVITY FUNCTION FOR LINES (EQ.47)  **
C
      EEP(J,L)=1.0  -  EXP(TAUL(J,IY)-TAUL(J,L))
   70 XLPP(J,L)=PHI2(ALPHAP) * SUM2
   69 CONTINUE
C
C **    DEBUG PRINT  **
      IF (IDG.EQ.99) CALL BUGPR (5)
C
   72 DO 80 J=1,9
      ASM1=0.
      ASM2=0.
      FM(J,IY)=0.
      IF (IY.EQ.1) GO TO 81
      DO 82 L=2,IY
      FM(J,IY)=FM(J,IY)  -  (WMM(J,L)-WMM(J,L-1))
     1        *(BEEL(J,L-1)+BEEL(J,L)) * 1.5707963
      IF (L.EQ.IY) GO TO 82
      ASM1=ASM1  -  (EEM(J,L)-EEM(J,L-1))
     1        * (BEEL(J,L-1) * XLMM(J,L-1) + BEEL(J,L) * XLMM(J,L))/2.
      ASM2=ASM2  -  (XLMM(J,L)-XLMM(J,L-1))
     1        * (BEEL(J,L-1) * EXP(TAUL(J,L-1)-TAUL(J,IY)) + BEEL(J,L)
     2        * EXP(TAUL(J,L)-TAUL(J,IY)))/2.0
   82 CONTINUE
   81 ASP1=0.
      ASP2=0.
      IYP=IY+1
      IF (IY.EQ.NES) GO TO 83
      DO 84 L=IYP,NES
      FP(J,IY)=FP(J,IY)  +  (WPP(J,L)-WPP(J,L-1))
     1        * (BEEL(J,L-1)+BEEL(J,L)) * 1.5707963
      IF (L.EQ.IYP) GO TO 84
      ASP1=ASP1  +  (EEP(J,L)-EEP(J,L-1))
     1        * (BEEL(J,L-1) * XLPP(J,L-1) + BEEL(J,L) * XLPP(J,L))/2.0
      ASP2=ASP2  +  (XLPP(J,L)-XLPP(J,L-1)) *
```

```
     1         (BEEL(J,L-1) * EXP(TAUL(J,IY)-TAUL(J,L-1))  +  BEEL(J,L)   TRANS410
     2         * EXP(TAUL(J,IY)-TAUL(J,L)))/2.0                           TRANS420
  84 CONTINUE                                                             TRANS430
  83 QLCP(J)=2.0 * FMUL(J,IY) * (FM(J,IY)+FP(J,IY))                       TRANS440
     SUMS=1.0                                                             TRANS450
     SUMT=0.                                                              TRANS460
     DO 86 M=1,4                                                          TRANS470
  86 SUMT=SUMT  +  SSM(J,M,IY) * WN(J,M)                                  TRANS480
     ATM1=0.                                                              TRANS490
     IF (IY.NE.1) ATM1=(BEEL(J,IY-1)+BEEL(J,IY)) /2.0 * EEM(J,IY-1)       TRANS500
     1         * XLMN(J,IY-1)                                             TRANS510
     ATP1=0.                                                              TRANS520
     IF(IY.NE.NES) ATP1=(BEEL(J,IY+1)+BEEL(J,IY))/2.0 * EEP(J,IY+1)       TRANS530
     1         * XLPP(J,IY+1)                                             TRANS540
     GCLP(J)=6.2831853  * SUMS * (ASM1+ASP1+ATM1+ATP1)                    TRANS550
     IF (IY.EQ.1) ATM2=-BEEL(J,IY) * SUMT                                 TRANS560
     IF (IY.NE.1) ATM2=(BEEL(J,IY-1)-BEEL(J,IY))  *  GMM(J,IY-1)          TRANS570
     1         -  BEEL(J,IY-1) * XLMM(J,IY-1)                             TRANS580
     IF (IY.EQ.NES) ATP2=-BEEL(J,IY) * SUMT                               TRANS590
     IF (IY.NE.NES)ATP2=(BEEL(J,IY+1)-BEEL(J,IY))  * GPP(J,IY+1)          TRANS600
     1         -  BEEL(J,IY+1) * XLPP(J,IY+1)                             TRANS610
     GLLP(J)=6.2831853 * SUMS*(-ASM2-ASP2+ATM2+ATP2)                      TRANS620
  80 CONTINUE                                                             TRANS630
     GCL(IYY)=0.                                                          TRANS640
     GLC(IYY)=0.                                                          TRANS650
     GLL(IYY)=0.                                                          TRANS660
     DO 85 J=1,9                                                          TRANS670
     GCL(IYY)=GCL(IYY)  +  GCLP(J)                                        TRANS680
     GLC(IYY)=GLC(IYY)  +  GLCP(J)                                        TRANS690
  85 GLL(IYY)=GLL(IYY)  +  GLLP(J)                                        TRANS700
1614 CONTINUE                                                             TRANS710
     DGN(IYY)=-(GCC(IYY)+GCL(IYY)+GLC(IYY)+GLL(IYY))                      TRANS720
C                                                                         TRANS730
C **   DEBUG PRINT  **                                                    TRANS740
C                                                                         TRANS750
      IF (IDG.EQ.0) GO TO 49                                              TRANS760
```

```
      CALL BUGPR(6)
   49 CONTINUE
      IEZ=IEZ-1
      DQ(1)=DON(1)
      L=2
      DO 1 N=2,NES
      DO 2 I=2,IEZ
      NP=I
      IF (ETZ(I).GT.ETA(N)) GO TO 3
    2 CONTINUE
    3 NN=NP-1
      AA=0.0
      ZB=(DON(NN)-DON(NP)) / (ETZ(NN)-ETZ(NP))
      CC=DON(NN)  -  ZB * ETZ(NN)
      DQ(N)=AA * ETA(N)**2  +  ZB * ETA(N)  +  CC
      GO TO 1
    4 DQ(N)=DON(NN)
    1 CONTINUE
C
C **  NON-DIMENSIONALIZE E(I)  **
      DO 250 I=1,NES
      T(I) = T(I)/TC
  250 E(I) = ((DQ(I)*XL )/(RINF*UINF**3))*20866.0 *RZB
      RETURN
      END
```

```
      SUBROUTINE SND(I)
      COMMON/PRCP1/PI(60),RHC(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMCN /RFLUX/ E(6C),IRAD,ITYPE
      COMMON /NCN/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/WT/SMW(20),AWT(5)
      COMMON /NUMDEN/ SNCC2(60), SNDN2(6C), SNDO(60), SNDN(60),
     1                                      SNDE(60), SNDC(60),
     2               SNDH(60), SNDC2(60), SNDH2(60), SNDCO(60),
     3               SNDC3(6C),SNDC2H(6C)
C     **  CALCULATE SPECIE NUMBER DENSITIES BASED ON MOLE FRACTIONS  **
C
      CONVER = 3.10375E+23 *RHC(I) *RDZ
C
      SNDO2(I) = CONVER * C( 1,I)/SMW( 1)
      SNDN2(I) = CONVER * C( 2,I)/SMW( 2)
      SNDO  (I) = CONVER * C( 3,I)/SMW( 3)
      SNDN  (I) = CONVER * C( 4,I)/SMW( 4)
      SNDE  (I) = CONVER * C( 7,I)/SMW( 7)
      SNDC  (I) = CONVER * C( 8,I)/SMW( 8)
      SNDH  (I) = CONVER * C( 9,I)/SMW( 9)
      SNDH2(I) = CONVER * C(10,I)/SMW(1C)
      SNDCC(I) = CONVER * C(11,I)/SMW(11)
      SNDC3(I) = CONVER * C(12,I)/SMW(12)
      SNDC2(I) = CONVER * C(19,I)/SMW(19)
      SNDC2H(I)= CONVER * C(14,I)/SMW(14)
      RETURN
      END
```

```
      SUBROUTINE LRAD
C
C
C  **  THIS IS A DRIVER PROGRAM FOR SUBROUTINE TRANS WHICH CALCULATES **
C      THE RADIATIVE FLUX DIVERGENCE THROUGH A ONE-DIMENSIONAL SLAB
C      FOR A GIVEN TEMPERATURE AND SPECIES DISTRIBUTION
      COMMON /SFLUX/ QRI(3)
      COMMON /TRN/          NUT(60), FMC(12,60), FPC(12,60),
     1             FM(9,60), FP(9,60), LINES
      COMMON /TEST/ETZ(60),IEZ
      COMMON /YL/ETA(60),YOND(60)
      COMMON/PROP1/PI(60),RHO(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /DEL/ DELTA,DTIL,DTILS
      COMMON /NCN/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON /MAIN/KEEP,MAXE,MAXM,MAXD,   IDG,MCONV,ECONV,DCONV,LT,IAB
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON /NUMDEN/ SNDO2(60), SNDN2(60), SNDO(60), SNDN(60),
     1                                     SNDE(60), SNDC(60),
     2                 SNDH(60), SNDC2(60), SNDH2(60), SNDCO(60),
     3                 SNDC3(60),SNDC2H(60)
      COMMON /SPEC/ MF, XMOL
C
C
C  **  NETA = NUMBER OF ETA POINTS
C      MF    = 1  IF SPECIE  MOLE FRACTIONS ARE INPUT AND NUMBER DENSITY
C                 TO BE COMPUTED
C               0  IF SPECIE NUMBER DENSITIES ARE INPUT
C      NS    = NUMBER OF SPECIES TO BE INPUT
C      LINES= 1  IF LINE CALCULATION IS TO BE DONE
C             0  IF ONLY CONTINUUM CALCULATION IS TO BE DONE
C      IDG   = 0  ONLY FINAL PRINT IS GIVEN
C              1  PRINT IS GIVEN FOR EACH ETA
C             99  COMPLETE PRINT
C
C
```

```
      CALL TRANS(1)                                                     LRAD 730
      IDG= IDGS                                                         LRAD 740
C                                                                       LRAD 750
C  **  INDEX IS NUMBER GIVEN SPECIE FOR USE IN STORING ARRAYS **        LRAD 760
C                         1    =    C2                                  LRAD 770
C                         2    =    N2                                  LRAD 780
C                         3    =    O                                   LRAD 790
C                         4    =    N                                   LRAD 800
C                         5    =    E-                                  LRAD 810
C                         6    =    C                                   LRAD 820
C                         7    =    H                                   LRAD 830
C                         8    =    C2                                  LRAD 840
C                         9    =    H2                                  LRAD 850
C                        10    =    CO                                  LRAD 860
C                        11    =    C3                                  LRAD 870
C                        12    =    C2H                                 LRAD 880
C                                                                       LRAD 890
C                                                                       LRAD 900
      RETURN                                                            LRAD 910
      END                                                               LRAD 920
```

```
      SUBROUTINE ZP(T1,SUMN,SUMO,SUMH,SUMC)
C
C     **  FRACTIONAL POPULATION STATES FOR N, O, H, C  **
C
      COMMON /ZPI/ ZPO(6), ZPN(6),ZPH(2),  ZPC(7)
      ZPH(1)=2.0/SUMH
      ZPH(2)=8.0 * EXP(-10.20/T1)/SUMH
      ZPC(1)=9.0/SUMC
      ZPC(2)=5.0 * EXP(-1.264/T1)/SUMC
      ZPC(3)=EXP(-2.684/T1)/SUMC
      ZPC(4)=5.0 * EXP(-4.183/T1)/SUMC
      ZPC(5)=12.0 * EXP(-7.532/T1)/SUMC
      ZPC(6)=36.0*EXP(-8.722/T1)/SUMC
      ZPC(7)=60.0 * EXP(-9.724/T1)/SUMC
      ZPN(1)=4.0/SUMN
      ZPN(2)=10.0* EXP(-2.384/T1)/SUMN
      ZPN(3)=6.0 * EXP(-3.576/T1)/SUMN
      ZPN(4)=18.0 * EXP(-10.452/T1)/SUMN
      ZPN(5)=54.0 * EXP(-11.877/T1)/SUMN
      ZPN(6)=90.0 * EXP(-13.002/T1)/SUMN
      ZPO(1)=9.0/SUMO
      ZPO(2)=5.0 * EXP(-1.967/T1)/SUMO
      ZPO(3)=EXP(-4.188/T1)/SUMO
      ZPO(4)=8.0 * EXP(-9.263/T1)/SUMO
      ZPO(5)=24.0 * EXP(-10.830/T1)/SUMO
      ZPO(6)=40.0 * EXP(-12.077/T1)/SUMO
C
      RETURN
      END
```

```
      SUBROUTINE TRANS2
C - - - AN OUTPUT SUBROUTINE FOR RADIATIVE FLUXES AND SPECIES
C       NUMBER DENSITIES - - -
      COMMON /SFLUX/ QRI(3)
      COMMON /YL/ETA(60),YOND(60)
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NES
      COMMON /TRN/          NUT(60), FNC(12,60), FPC(12,60),
     1              FM(9,60), FP(9,60), LINES
      COMMON /FINV/ NHVL,NIHVC,FHVC(12),CJ(9),HVJ(9),ZKZ
      COMMON /TEST/ETZ(60),IEZ
      COMMON /NUMDEN/ SNCO2(60), SNCN2(60), SNDO(60), SNDN(60),
     1                                      SNDE(60), SNDC(60),
     2                SNDH(60), SNDC2(60), SNDH2(60), SNDCO(60),
     3                SNDC3(60),SNDC2H(60)
      COMMON /SPEC/ MF, XMOL
      COMMON /VEL/ F(60),FC(60),Z(60),V(60)
      DIMENSION ETOUT(3)
      NETA=NES
      ETOUT(1)=0.0
      ETOUT(3)=1.0
      NS =0
      DO 10 I=1,NES
      IF(V(I).LT.0.0) GO TO 15
   10 NS=NS+1
   15 CONTINUE
      ETOUT(2) = ETA(NS+1)
      IF(NS.LE.1) ETOUT(2) = ETA(29)
   17 CONTINUE
      DO 20 K=1,IEZ
      IF(ETOUT(2).EQ.ETZ(K)) GO TO 25
   20 CONTINUE
      NS = NS+1
      ETOUT(2) = ETA(NS+1)
      GO TO 17
   25 CONTINUE
      NOUT=3
```

```
C
C   OUTPUT FLUX
C
      WRITE (6,600)
      WRITE (6,603)  (ETA(I),SNDN2(I),SNDC2(I),SNDN(I),SNDO(I),
     1                        SNDE(I), SNDH(I),
     2                      SNDC(I),SNDC2(I),SNDH2(I),SNDCO(I),SNDC3(I),
     3                SNDC2H(I),                I=1,NETA)
C **   CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX **
C
      WRITE (6,4103)
      DO 8040 K=1,NCUT
      DO 8041 LK=1,NES
      NUT(K)=LK
      IF (ABS(ETCUT(K)-ETA(LK)) - 1.0E-05) 8040,8040,8041
 8041 CONTINUE
 8040 CONTINUE
      L1=NUT(1)
      L2=NUT(2)
      L3=NUT(3)
      WRITE (6,8037)(ETCUT(IL),IL=1,3)
      FM1=0.0
      FP1=0.0
      FM2=0.0
      FP2=0.0
      FM3=0.0
      FP3=0.0
      DO 4104 KL=1,NIHVC
      WRITE (6,8042) KL,   FHVC(KL),   FMC(KL,L1),   FPC(KL,L1),
     1              FMC(KL,L2),   FPC(KL,L2),  FMC(KL,L3),    FPC(KL,L3)
      FM1=FM1  +  FMC(KL,L1)
      FP1=FP1  +  FPC(KL,L1)
      FM2=FM2  +  FMC(KL,L2)
      FP2=FP2  +  FPC(KL,L2)
      FM3=FM3  +  FMC(KL,L3)
      FP3=FP3  +  FPC(KL,L3)
```

```
 4104 CONTINUE
      WRITE (6,8045) FM1,   FP1,   FM2,   FP2,   FM3,   FP3
      QRI(1)=FM1+FP1
      QRI(2)=FM2+FP2
      QRI(3)=FM3+FP3
C
C **   LINE      CONTRIBUTION TO THE SPECTRAL FLUX **
C
      IF (LINES.EQ.0) RETURN
      WRITE (6,8035)
      WRITE (6,8037) (ETCUT(IL),IL=1,3)
      FM1=0.0
      FP1=0.0
      FM2=0.0
      FP2=0.0
      FM3=0.0
      FP3=0.0
C
C **   TOTAL FLUX CALCULATION   **
C
      DO 8043 KL=1,NHVL
      WRITE (6,8C42) KL,   HVJ(KL),   FM(KL,L1),   FP(KL,L1),
     1           FM(KL,L2),   FP(KL,L2),   FM(KL,L3),   FP(KL,L3)
      FM1=FM1   +  FM(KL,L1)
      FP1=FP1   +  FP(KL,L1)
      FM2=FM2   +  FM(KL,L2)
      FP2=FP2   +  FP(KL,L2)
      FM3=FM3   +  FM(KL,L3)
      FP3=FP3   +  FP(KL,L3)
 8043 CONTINUE
      WRITE (6,8045) FM1,   FP1,   FM2,   FP2,   FM3,   FP3
      QRI(1)=QRI(1)   +  FM1   +  FP1
      QRI(2)=QRI(2)   +  FM2   +  FP2
      QRI(3)=QRI(3)   +  FM3   +  FP3
C
  600 FORMAT (1H1,33HNUMBER DENSITIES   (PARTICLES/CM3) ///5X,3HETA, 8X,
```

```
     1          2HN2, 8X,2HC2, 8X,1HN, 8X,1HO, 8X, 2HE-,8X,            TRAN1090
     2 1HH,8X,1HC, 8X,2HC2, 8X,2HH2, 8X,2HCO, 8X,2HC3,8X,3HC2H///)     TRAN1100
  603 FORMAT (1P13E10.2)                                                TRAN1110
 4103 FORMAT (44H1CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX)          TRAN1120
 8035 FORMAT (39H0LINE CONTRIBUTION TO THE SPECTRAL FLUX)               TRAN1130
 8037 FORMAT (/22X,5HETA =F7.3,13X,5HETA =F7.3,13X,5HETA =F7.3//3X,1HI, TRAN1140
     1 3X,3HHNU,8X,6HQMINUS,7X,5HQPLUS,8X,6HQMINUS,7X,5HQPLUS,8X,      TRAN1150
     2 6HQMINUS,7X,5HQPLUS/)                                            TRAN1160
 8042 FORMAT (I4,F8.3,1P8E13.3)                                         TRAN1170
 8045 FORMAT (12H0TOTAL FLUX ,1P8E13.3)                                 TRAN1180
      RETURN                                                            TRAN1190
      END                                                               TRAN1200
```

```
      SUBROUTINE BUGPR (IDGSW)
C - - -  A DEBUG SUBROUTINE FOR TRANS - - -
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NES
      COMMON /YL/ETA(60),  YD(60)
      COMMON /TRN/         NUT(60), FMC(12,60), FPC(12,60),
     1             FM(9,60),  FP(9,60), LINES
      COMMON /DBLG/ QLC(60), QCL(60), QLL(60), DQN(60), QCC(60),
     1             BEEC(12,60),    FMUC(12,60),    EM(12,60),
     2             EP(12,60),      TAUC(12,60),    BEEL(9,60),
     3             QCCP(12),       WMM(9,60),      GMM(9,60),
     4             EEM(9,60),      XLMM(9,60),     QLCP(9),
     5             QCLP(9),        QLLP(9),        DELTA,     IY,   IYY,
     6             WPP(9,60),      GPP(9,60),      EEP(9,60),
     7             XLPP(9,60),     FG(9,4),        GP(9,4),
     8             WN(9,4),        FMUL(9,60),     SSM(9,4,60),
     9             GGM(9,4,60),    ETAM(9,4,60),   SDM(9,4,60),
     A             TAUL(9,60)
      GO TO (10,20,30,40,50,60,70), IDGSW
   10              WRITE (6,194)
  194 FORMAT (1H1)
      RETURN
   20 WRITE (6,7182) DELTA
 7182 FORMAT (7HODELTA=1PE14.7,3H CM)
      RETURN
   30 WRITE (6,190) IY,   YD(IY)
  190 FORMAT (4H1IY=I3,2X,3HYD=1PE12.5//2X,1HK,2X,1HL,7X,3HETA,13X,2HYD,
     1 13X,2HMU,11X,3HTAU,14X,1HE,11X,3HBEE//)
      DO 22 K=1,12
      IF (IY.EQ.1) GO TO 23
      WRITE(6,191) (K,   L,   ETA(L),   YD(L),   FMUC(K,L),   TAUC(K,L),
     1             EM(K,L),   BEEC(K,L),   L=1,IY)
  191 FORMAT (2I3,1P6E15.5)
      WRITE (6,192)
  192 FORMAT (//)
   23 IF (IY.EQ.NES) GO TO 22
      WRITE (6,191) (K,   L,   ETA(L),   YD(L),   FMUC(K,L),
```

```
                    TAUC(K,L),    EP(K,L),    BEEC(K,L),    L=IY,NES)        BUGP 370
     1                                                                          
   22 WRITE (6,193) FMC(K,IY),    FPC(K,IY),    QCCP(K)                          BUGP 380
  193 FORMAT (5HOFIM=1PE12.5 ,2X,4HFIP=E12.5,2X,5HQCCP=E12.5)                    BUGP 390
      RETURN                                                                     BUGP 400
   40                WRITE (6,195) IY,    YD(IY),    ((J,    L,    YD(L),        BUGP 410
     1              WMM(J,L),    GMM(J,L),    XLMM(J,L),    EEM(J,L),            BUGP 420
     2              BEEL(J,L),    L=1,IY),    J=1,9)                             BUGP 430
  195 FORMAT (4HOIY=I3,2X,3HYY=1PE12.5//2X,1HJ,2X,1HL,7X,2HYD,12X,3HWMM,BUGP 440
     1 12X,3HGMM,11X,4HXLMM,13X,3HEEM,13X,3HBEE//(2I3,6E16.5))                   BUGP 450
      RETURN                                                                     BUGP 460
   50                WRITE (6,196) IY,    YD(IY),    ((J,    L,    YD(L),        BUGP 470
     1          WPP(J,L),    GPP(J,L),    XLPP(J,L),    EEP(J,L),                BUGP 480
     2          BEEL(J,L),    L=IY,NES),    J=1,9)                               BUGP 490
  196 FORMAT (4HOIY=I3,2X,3HYY=1PE12.5//2X,1HJ,2X,1HL,7X,2HYD,13X,3HWPP,BUGP 500
     1 2X,3HGPP,11X,4HXLPP,13X,3HEEP,13X,3HBEE//(2I3,6E16.5))                    BUGP 510
      RETURN                                                                     BUGP 520
   60 WRITE (6,198) IY,    ETA(IY),    YD(IY)                                    BUGP 530
  198 FORMAT (4HOIY=I3,2X,4HETA=1PE12.5,2X,3HYY=E12.5//2X,1HJ,5X,3HQCC,  BUGP 540
     1 11X,3HFMC,11X,3HFPC,11X,3HQCL,11X,3HQLC,11X,3HQLL,12X,2HFM,12X,   BUGP 550
     2 2HFP,11X,3HDQN//)                                                         BUGP 560
      WRITE (6,199) (J,    QCCP(J),    FMC(J,IY),    FPC(J,IY),              BUGP 570
     1              QCLP(J),    QLCP(J),    QLLP(J),    FM(J,IY),FP(J,IY),   BUGP 580
     2              J=1,9)                                                       BUGP 590
  199 FORMAT (I3,1P8E14.5)                                                       BUGP 600
      WRITE (6,8069) (J,    QCCP(J),    FMC(J,IY),    FPC(J,IY),    J=10,12)BUGP 610
 8069 FORMAT (I3,1P3E14.5)                                                       BUGP 620
      WRITE (6,200) QCC(IYY),    QCL(IYY),    QLC(IYY),    QLL(IYY),         BUGP 630
     1              DQN(IYY)                                                     BUGP 640
  200 FORMAT (1HO,2X,1PE14.5,28X,3E14.5,28X,E14.5)                               BUGP 650
      RETURN                                                                     BUGP 660
   70 WRITE (6,197) L,    ETA(L),    YD(L),    ((J,    M,    WN(J,M),            BUGP 670
     1              FG(J,M),    GP(J,M),    FMUL(J,L),    TAUL(J,L),             BUGP 680
     2              SSM(J,M,L),    GGM(J,M,L),    ETAM(J,M,L),    SBM(J,M,L),BUGP 690
     3              M=1,4),J=1,9)                                                BUGP 700
  197 FORMAT (3HCL=I3,2X,4HETA=1PE12.5,2X,3HYD=E12.5//2X,1HJ,2X,1HM,7X,  BUGP 710
     1 1HN,13X,1HF,13X,1HG,11X,3HFML,11X,3HTAU,11X,3HSSM,11X,3HGGM,10X,  BUGP 720
```

```
2 4HETAM,11X,3HSBM//(2I3,9E14.5))                                   BUGP 730
  RETURN                                                            BUGP 740
  END                                                               BUGP 750
```

```
      SUBROUTINE ZHV(HV,ZC,ZN,ZI,ZC)
C
C
C  **  THIS SUBROUTINE CALCULATES THE QUANTUM MECHANICAL CORRECTION
C          FACTORS GIVEN A FREQUENCY (HV) **
C
      X= HV
      X2 =X*X
      X3 =X2*X
      X4 =X3*X
      X5 =X4*X
      X6 =X5*X
      X7 =X6*X
      IF (X -9.82) 1,1,2
    1 ZO = .9999795              -.3155480*X          +2.824548 E-02*X2
     1     +6.677328 E-03*X3     -3.644585 E-03*X4    +8.058070 E-04*X5
     2     -7.708637 E-05*X6     +2.668133 E-06*X7
      GO TO 3
    2 ZO = (X/9.82)**3
    3 IF (X -8.35) 4,4,5
    4 ZN = 1.000148              - .4183535 *X        + .1680359 *X2
     1     -9.779458 E-02*X3     +3.354635 E-02*X4    -5.609353 E-03*X5
     2     +4.515535E-04*X6      -1.403585 E-05*X7
      GO TO 6
    5 ZN = (X/8.35)**3
    6 Y = X/4.0
      IF (Y-0.6) 9,9,10
    9 Y2 =Y*Y
      Y3 =Y2*Y
      Y4 =Y3*Y
      Y5 =Y4*Y
      Y6 =Y5*Y
      Y7 =Y6*Y
      ZI = 1.000379              - .2964767 *Y        +7.505242 E-02*Y2
     1     -1.702948E-02*Y3      +3.279554 E-03*Y4    -2.128469 E-04*Y5
      GO TO 11
```

```
10    ZI = (Y/6.6)**3                                                                  ZHV( 370
11    IF (X-7.37) 12,12,13                                                             ZHV( 380
12    ZC =    .9974367             - .4341812 *X          +8.531314 E-02*X2            ZHV( 390
     1      -1.393917 E-02*X3      +4.038545 E-03*X4      -5.426425 E-04*X5            ZHV( 400
     2      +2.812126 E-05*X6      -3.883530 E-07*X7                                   ZHV( 410
      GO TO 14                                                                         ZHV( 420
13    ZC = (X/7.37)**3                                                                 ZHV( 430
14    RETURN                                                                           ZHV( 440
      END                                                                              ZHV( 450
```

```
      SUBROUTINE RADIN
C - - -   AN INITIALIZATION SUBROUTINE FOR TRANS - - -
      COMMON /DBLG/ QLC(60), QCL(60), QLL(60), DON(60), QCC(60),
     1              BEEC(12,60),   FMUC(12,60),   EM(12,60),
     2              EP(12,60),     TAUC(12,60),   BEEL(9,60),
     3              QCCP(12),      WMM(9,60),     GMM(9,60),
     4              EEM(9,60),     XLMM(9,60),    QLCP(9),
     5              QCLP(9),       QLLP(9),       DELTA,     IY,   IYY,
     6              WPP(9,60),     GPP(9,60),     EEP(9,60),
     7              XLPP(9,60),    FG(9,4),       GP(9,4),
     8              WN(9,4),       FMUL(9,60),    SSM(9,4,60),
     9              GGM(9,4,60),   ETAM(9,4,60),  SBM(9,4,60),
     A              TAUL(9,60)
C  **  GROUP 1  **
      WN(1,1)=0.
      FG(1,1)=0.
      GP(1,1)=0.
      WN(1,2)=18.
      WN(1,3)=15.
      WN(1,4)=5.
C  **  GROUP 2  **
      WN(2,1)=3.0
      WN(2,2)=5.0
      WN(2,3)=11.0
      WN(2,4)=10.
C  **  GROUP 3  **
      WN(3,1)=0.
      FG(3,1)=0.
      GP(3,1)=0.
      WN(3,2)=2.0
      WN(3,3)=0.
      FG(3,3)=0.
      GP(3,3)=0.
      WN(3,4)=0.
      FG(3,4)=0.
      GP(3,4)=0.
```

```
C   **   GROUP 4   **                                                   RADI 370
      WN(4,1)=0.                                                        RADI 380
      FG(4,1)=0.                                                        RADI 390
      GP(4,1)=0.                                                        RADI 400
      WN(4,2)=8.0                                                       RADI 410
      WN(4,3)=2.0                                                       RADI 420
      WN(4,4)=0.                                                        RADI 430
      FG(4,4)=0.                                                        RADI 440
      GP(4,4)=0.                                                        RADI 450
C   **   GROUP 5   **                                                   RADI 460
      WN(5,1)=0.                                                        RADI 470
      FG(5,1)=0.                                                        RADI 480
      GP(5,1)=0.                                                        RADI 490
      WN(5,2)=14.                                                       RADI 500
      WN(5,3)=4.0                                                       RADI 510
      WN(5,4)=1.0                                                       RADI 520
C   **   GROUP 6   **                                                   RADI 530
      WN(6,1)=1.0                                                       RADI 540
      WN(6,2)=4.0                                                       RADI 550
      WN(6,3)=13.0                                                      RADI 560
      WN(6,4)=2.0                                                       RADI 570
C   **   GROUP 7   **                                                   RADI 580
      WN(7,1)=0.                                                        RADI 590
      FG(7,1)=0.                                                        RADI 600
      GP(7,1)=0.                                                        RADI 610
      WN(7,2)=6.0                                                       RADI 620
      WN(7,3)=14.0                                                      RADI 630
      WN(7,4)=3.0                                                       RADI 640
C   **   GROUP 8   **                                                   RADI 650
      WN(8,1)=2.0                                                       RADI 660
      WN(8,2)=2.0                                                       RADI 670
      WN(8,3)=11.                                                       RADI 680
      WN(8,4)=15.                                                       RADI 690
C   **   GROUP 9   **                                                   RADI 700
      WN(9,1)=0.                                                        RADI 710
      FG(9,1)=0.                                                        RADI 720
```

```
      GP(9,1)=0.                                                        RADI 730
      WN(9,2)=1.0                                                       RADI 740
      WN(9,3)=11.                                                       RADI 750
      WN(9,4)=10.                                                       RADI 760
      RETURN                                                            RADI 770
      END                                                               RADI 780
```

```
      SUBROUTINE CHEMEQ( NI,NF)
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C                                                                     *
C     THIS SUBPROGRAM IS A REVISION OF A PROGRAM ORIGINALLY WRITTEN   *
C     BY EDUARDO G. DEL VALLE.  THE PROGRAM COMPUTES FOR A GIVEN      *
C     PRESSURE ARRAY,PP(N),TEMPERATURE ARRAY,TT(N), AND AN ARRAY      *
C     OF ELEMENTAL MASS FRACTIONS-CC(I,N). THE EQUILIBRIUM SPECIES    *
C     MASS FRACTIONS AT EACH POINT-N REPRESENTED BY THE GIVEN ARRAYS. *
C     THE EQUILIBRIUM COMPOSITIONS ARE STORED IN THE MATRIX CE(I,N).  *
C                                                                     *
C                                     DONALD D. ESCH                  *
C                                     LOUISIANA STATE UNIVERSITY      *
C                                     AUGUST 7, 1970                  *
C                                                                     *
C                                                                     *
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     IN = INITIAL POINT FOR EQUILIBRIUM CALCULATIONS.                *
C     NF = FINAL POINT.                                               *
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      COMMON/SP1/NDBLG
      COMMON/PRCP1/PP(60),RO(60),TT(60),AMW(60),CE(20,60),CC(5,60)
      COMMON/EQ1/AI(20), BI(20), CI(20), DI(20), EI(20), FI(20), GI(20),
     X          AII(20),BII(20),CII(20),DII(20),EII(20),FII(20),GII(20)
      COMMON/EQ2/AA(20,5),ICODE(20)
      COMMON/THERM1/C(20),FURT(20)
      COMMON/ID/SP(20),EL(5)
      COMMON/NUMBER/NS ,NNS,MM,NC
      COMMON /RP/ DUC,DPHI,TD,RZB,PC,HD,HTOTAL
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON/WT/XMW(20),AWT(5)
      DIMENSION R(7,7),B(7,1),YINT(20),FY(20),PI(7),FSUM(20),YSUM(20),
     1  X(20),DELT(20),XLAM(20)
      DIMENSION E(5),BD(5),Y(20)
C
      MA=1
C
```

```
C-----INITIAL GUESS FOR EQUILIBRIUM CALCULATIONS....
C
      DO10I=1,NS
 10   Y(I) = CWALL(I)*AMW(NI)/XMW(I)
C
C-----COMPUTE THE SIZE OF THE MATRIX
C
      NA=MM+1
C
C     NS=NUMBER OF SPECIES....
C
C     CRIT=CRITERIA FOR CONVERGENCE.
C
      CRIT = .005
      XBETA=CRIT
      BETA=0.
      LL=NS+1
      TOLD = 0.0
C
C     THE REMAINDER OF THE PROGRAM COMPUTES EQUILIBRIUM COMPOSITIONS
C     CORRESPONDING TO THE ELEMENTAL MASS FRACTIONS IN THE CC-ARRAY
C     FROM POINT N = NI TO POINT N = NF.
C
      DO5CCON=NI,NF
      IF(ABS(TT(N)-TOLD).LT.5.E-4) GO TO 800
      T = TT(N)*TD
      P=PP(N)
      NT=1
      BETOLD=0.0
C
C     DO20 I=1,MM
C     IF(CC(I,N).LT.1.0E-20)CC(I,N)=1.0E-20
C20   E(I)=CC(I,N)
C
C     CALL ALTERY(E,Y)
C
```

```
      DO25 J=1,MM
      BB(J)=0.0
      DO 25  I=1,NS
 25   BB(J)=BB(J)+AA(I,J)*Y(I)
C
      CALL THERMO(T,P)
C
C-----THERMO SUBROUTINE CALCULATES THE FREE ENRGY FUNCION.THE HEAT OF
C     FORMATION OF EVERY CHEMICAL SPECIE AT ANY TEMPERATURE T....
C
C
C-----SET-UP THE R-MATRIX AND THE B-VECTOR....
C
 40   YBAR=0.
      DO50I=1,NS
      IF(Y(I).LT.0.)Y(I)=1.E-73
   50 YBAR=YBAR+Y(I)
C
C     YBAR IS THE TOTAL NUMBER OF MOLES OF GAS SPECIES
C
C
C-----CALCULATE THE FREE ENERGY PARAMETER OF THE GAS SPECIES
C
      DO60I=1,NS
      FAC=Y(I)/YBAR
      IF(FAC.LT.1.E-73)FAC=1.E-73
 60   FY(I)=Y(I)*(C(I)+ALOG(FAC))
C
C-----PROCEED TO CONSTRUCT THE R MATRIX
C
C-----INITIALIZE TO ZERO....
C
      DO75J=1,NA
      DO75K=1,NA
 75   R(J,K)=0.0
C
```

```
      DO90J=1,MM                                                        CHEM1090
      DO90K=J,MM                                                        CHEM1100
      SUM=0.                                                            CHEM1110
      DO80I=1,NS                                                        CHEM1120
   80 SUM=SUM+AA(I,J)*AA(I,K)*Y(I)                                      CHEM1130
      R(J,K)=SUM                                                        CHEM1140
   90 R(K,J)=SUM                                                        CHEM1150
C                                                                       CHEM1160
      DO 103 K=1,MM                                                     CHEM1170
      SUM=0.                                                            CHEM1180
      DO 101 I=1,NS                                                     CHEM1190
  101 SUM=SUM+AA(I,K)*Y(I)                                              CHEM1200
      R(K,NA)=SUM                                                       CHEM1210
      R(NA,K)=SUM                                                       CHEM1220
  103 CONTINUE                                                          CHEM1230
C                                                                       CHEM1240
C ----PROCEED TO CALCULATE THE VECTOR B.                                CHEM1250
C                                                                       CHEM1260
      DO140J=1,MM                                                       CHEM1270
      SUM=0.                                                            CHEM1280
      DO130I=1,NS                                                       CHEM1290
  130 SUM=SUM+AA(I,J)*FY(I)                                             CHEM1300
  140 B(J,1)=SUM+EB(J)                                                  CHEM1310
C                                                                       CHEM1320
      SUM=0.                                                            CHEM1330
      DO150I=1,NS                                                       CHEM1340
  150 SUM=SUM+FY(I)                                                     CHEM1350
      B(NA,1)=SUM                                                       CHEM1360
C                                                                       CHEM1370
C-----MATRIX INVERSION IS CALLED TO PROVIDE THE SOLUTION FOR            CHEM1380
C     THE LINEARIZED EQUATIONS. THE SOLUTION OF THE EQUATIONS           CHEM1390
C     GIVES THE LAGRANGIAN MULTIPLIERS NEEDED TO COMPUTE THE MOLES      CHEM1400
C     OF EACH GAS SPECIES.                                              CHEM1410
C                                                                       CHEM1420
      CALL MATINV(R,NA,B,MA,NMAX)                                       CHEM1430
C                                                                       CHEM1440
```

```
      DO160I=1,NA                                                       CHEM1450
C                                                                       CHEM1460
C     PI(I)=LAGRANGINA MULTIPLIERS                                      CHEM1470
C                                                                       CHEM1480
  160 PI(I)=B(I,1)                                                      CHEM1490
      U=PI(NA)                                                          CHEM1500
      XBAR=U*YBAR                                                       CHEM1510
C                                                                       CHEM1520
C-----COMPUTE THE MOLES OF EACH SPECIE....                              CHEM1530
C                                                                       CHEM1540
      DO170I=1,NS                                                       CHEM1550
  170 FSUM(I)=-FY(I)+(Y(I)/YBAR)*XBAR                                   CHEM1560
      DO200I=1,NS                                                       CHEM1570
      PSUM=0.                                                           CHEM1580
      DO180J=1,MM                                                       CHEM1590
  180 PSUM=PSUM+PI(J)*AA(I,J)                                           CHEM1600
      YSUM(I)=PSUM*Y(I)                                                 CHEM1610
  200 X(I)=FSUM(I)+YSUM(I)                                              CHEM1620
C                                                                       CHEM1630
C-----COMPUTE THE CONVERGENCE PARAMENTER XLAMBD                         CHEM1640
C                                                                       CHEM1650
      XLAMBD=1.                                                         CHEM1660
      DO210 I=1,NS                                                      CHEM1670
      DELT(I)=X(I)-Y(I)                                                 CHEM1680
      IF(ABS(DELT(I)).LT.1.0E-20)DELT(I)=1.0E-20                        CHEM1690
      IF(DELT(I).GE.0.)GOTO210                                          CHEM1700
      IF(X(I).GT.0.)GOTO210                                             CHEM1710
      XLAM(I)=-Y(I)/DELT(I)                                             CHEM1720
      XLAMBD=AMIN1(XLAMBD,XLAM(I))                                      CHEM1730
      XLAMBD=.99*XLAMBD                                                 CHEM1740
  210 CONTINUE                                                          CHEM1750
      XLAM1=XLAMBD                                                      CHEM1760
      DEBAR=0.                                                          CHEM1770
      DO220I=1,NS                                                       CHEM1780
  220 DEBAR=DEBAR+DELT(I)                                               CHEM1790
C                                                                       CHEM1800
```

```
C-----DETERMINE THE SIZE OF THE UNIT VECTOR XLAMBD.                       CHEM1810
C      NEXT ITERATION. WHEN THE VALUE OF XLAMBD IS VERY SMALL SET THE     CHEM1820
C      VALUES OF Y(I) EQUAL TO X(I) TO AVOID USING THE SAME VALUES OF     CHEM1830
C      Y(I) AS WAS USED IN THE PREVIOUS ITERATION                         CHEM1840
C      APPLY THE CORRECTIONS TO OBTAIN A NEW SET OF ESTIMATES FOR THE     CHEM1850
C                                                                         CHEM1860
C                                                                         CHEM1870
C                                                                         CHEM1880
C-----DETERMINE THE FREE ENERGY GRADIENT.  IF POSITIVE REDUCE XLAMBDA     CHEM1890
C      DFDL=FREE ENERGY GRADIENT                                          CHEM1900
C                                                                         CHEM1910
 230   DFDL=0.                                                            CHEM1920
       DO280I=1,NS                                                        CHEM1930
       FAC=(Y(I)+XLAMBD*DELT(I))/(YBAR+XLAMBD*DEBAR)                      CHEM1940
       IF(FAC.GT.0.)GOTO260                                               CHEM1950
       XLAMBD=.9*XLAMBD                                                   CHEM1960
       GOTO230                                                            CHEM1970
 260   DERP=(DELT(I)*YBAR-DEBAR*Y(I))/(YBAR+XLAMBD*DEBAR)                 CHEM1980
       IF(FAC.LT.1.E-73)FAC=1.E-73                                        CHEM1990
 280   DFDL=DFDL+DELT(I)*(C(I)+ALOG(FAC)) + DERP                          CHEM2000
       IF(DFDL.LT.0.000)GOTO300                                           CHEM2010
       XLAMBD=.8*XLAMBD                                                   CHEM2020
       IF(XLAMBD.GT.1.0E-08)GOTO230                                       CHEM2030
C                                                                         CHEM2040
C-----THE VALUE OF XLAMBD THAT ASSURES CONVERGENCE HAS BEEN FOUND         CHEM2050
C                                                                         CHEM2060
 300   DO350I=1,NS                                                        CHEM2070
       IF(XLAMBD.GT.1.E-6)GOTO330                                         CHEM2080
       IF(DFDL.LT.0.)GOTO330                                              CHEM2090
       IF(XLAM1.LT.1.E-6)XLAM1=1.E-6                                      CHEM2100
C                                                                         CHEM2110
C-----CALCUALTE THE NEW COMPOSITION FOR THE NEXT ITERATION                CHEM2120
C                                                                         CHEM2130
       Y(I)=Y(I)+XLAM1*DELT(I)*.1                                         CHEM2140
       GOTO350                                                            CHEM2150
 330   Y(I)=Y(I)+XLAMBD*DELT(I)                                           CHEM2160
 350   CONTINUE
```

```
C
C-----CHECK IF CONVERGENCE CRITERIA HAS BEEN MET. IF NOT GO BACK TO
C     STATEMENT 40....
C
      BETA=0.0
      DO400I=1,NS
 400  BETA=BETA+ABS(DELT(I))
      IF(BETA.GT.BETOLD)GOTO532
      IF(BETA.LT.XBETA)GOTO800
C
C
 532  NT=NT+1
      BETOLD=BETA
      TOLD = TT(N)
C
C-----IF THE NUMBER OF ITERATIONS EXCEED 900 STOP COMPUTATIONS
C
      IF(NT.GT.900)GOTO6000
      GOTO40
C
C**********************************************************************
C-----CONVERGENCE HAS BEEN ACHIEVED.                                  *
C**********************************************************************
C
 800  CONTINUE
C
C-----CONVERT Y(I) TO MOLE FRACTIONS.....
C
C     THESE VALUES IN THE CE-MATRIX.  AMW(N) IS THE AVERAGE MOLECULAR
C     CONVERT EQUILIBRIUM MOLE FRACTIONS TO MASS FRACTIONS AND STORE
C     WEIGHT AT THE POINT, N.
C
      SUMY=0.0
      DO900I=1,NS
 900  SUMY=SUMY+Y(I)
      AMW(N) = 0.0
```

```
      DO1000I=1,NS
      Y(I)=Y(I)/SUMY
 1000 AMW(N) = AMW(N) + Y(I)*XMW(I)
      DO1005I=1,NS
 1005 CE(I,N) = Y(I)*XMW(I)/AMW(N)
C
C     OPTIONAL OUTPUT OF POSITION , TEMPERATURE AND EQUILIBRIUM
C     COMPOSITIONS.
C
      IF(NDBUG.LT.2)GOTO3300
      PRINT 2000,P,TT(N),NT
 2000 FORMAT(//,'  P = ',F5.3,' T(DK) = ',F6.0,5X,'NUMBER OF ITERATIONS
     X=',I3,//,11X,'Y(I)',12X,'C(I,N)',/)
      PRINT 2005,(SP(I),Y(I),CE(I,N),I=1,NS)
 2005 FORMAT(1X,A4,2E18.8)
C
 3300 XBETA=CRIT
 5000 CONTINUE
      RETURN
 6000 PRINT6001
 6001 FORMAT( ' NUMBER OF ITERATIONS EXCEEDED 900, PROGRAM TERMINATING')
      RETURN
      END
```

```
      SUBROUTINE THERMO(T,P)
C
C
C-----SUBROUTINE THERMO CALCULATES THE FREE ENERGY FUNCTION FOR EACH
C     CHEMICAL SPECIE.
C
C
      COMMON/NUMBER/NQ ,NNS,NE,NC
      COMMON/EQ1/AI(20), BI(20), CI(20), DI(20), EI(20), FI(20), GI(20),
     X        AII(20),BII(20),CII(20),DII(20),EII(20),FII(20),GII(20)
      COMMON/EQ2/AA(20,5),ICODE(20)
      COMMON/THERM1/C(20),FORT(20)
C
C     T=TEMPERATURE IN OK
C
      T1=T
      T2=T1*T
      T3=T2*T
      T4=T3*T
      T5=T4*T
C
C
C-----CALCUALTE THE FREE ENERGY FUNCTION FORT(I)
C
C     FORT(I)=FREE ENERGY FUNCTION
C
      DO 41 I=1,NQ
      IF(T.GT.6000.  )GOTO6205
      FORT(I)=AI(I)*(1.-ALOG(T))-BI(I)*T/2.-CI(I)*T2/6.-DI(I)*T3/12.
     1          -EI(I)*T4/20.+FI(I)/T-GI(I)
      IF(ICODE(I).EQ.1)GOTO41
      C(I)=FORT(I)+ALOG(P)
      GOTO41
 6205 FORT(I)=AII(I)*(1.-ALOG(T))-BII(I)*T/2.-CII(I)*T2/6.-DII(I)*T3/12.
     1          -EII(I)*T4/20.+FII(I)/T-GII(I)
      IF(ICODE(I).EQ.1)GOTO41
```

```
      C(I)=FORT(I)+ALOG(P)
   41 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MATINV(A,N,B,M,NMAX)
C
C
C     MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS
      DIMENSION A(7,7),B(7,1),IPIVOT(7),INDEX(7,2)
      EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX,T,SWAP)
C
C     INITIALIZATION
C
    5 ISCALE=0
    6 R1=10.0**18
    7 R2=1.0/R1
   10 DETERM=1.0
   15  DO 20 J=1,N
   20 IPIVOT(J)=0
   30 DO 550 I=1,N
C
C     SEARCH FOR PIVOT ELEMENT
C
   40 AMAX=0.0
   45 DO 105 J=1,N
   50 IF (IPIVOT(J)-1)60,105,60
   60 DO 100 K=1,N
   70 IF (IPIVOT(K)-1)80,100,740
   80 IF (ABS(AMAX)-ABS(A(J,K)))85,100,100
   85 IROW=J
   90 ICOLUM=K
   95 AMAX=A(J,K)
  100 CONTINUE
  105 CONTINUE
      IF (AMAX)110,106,110
  106 DETERM=0.0
      ISCALE=0
      GO TO 740
  110 IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
C
```

```
C      INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
  130 IF (IROW-ICOLUM)140,260,140
  140 DETERM=-DETERM
  150 DO 200 L=1,N
  160 SWAP=A(IROW,L)
  170 A(IROW,L)=A(ICOLUM,L)
  200 A(ICOLUM,L)=SWAP
  205 IF(M)260,260,210
  210 DO 250 L=1,M
  220 SWAP=B(IROW,L)
  230 B(IROW,L)=B(ICOLUM,L)
  250 B(ICOLUM,L)=SWAP
  260 INDEX(I,1)=IROW
  270 INDEX(I,2)=ICOLUM
  310 PIVOT=A(ICOLUM,ICOLUM)
C
C      SCALE THE DETERMINANT
C
 1000 PIVOTI=PIVOT
 1005 IF(ABS(DETERM)-R1)1030,1010,1010
 1010 DETERM=DETERM/R1
      ISCALE=ISCALE+1
      IF(ABS(DETERM)-R1)1060,1020,1020
 1020 DETERM=DETERM/R1
      ISCALE=ISCALE+1
      GO TO 1060
 1030 IF(ABS(DETERM)-R2)1040,1040,1060
 1040 DETERM=DETERM*R1
      ISCALE=ISCALE-1
      IF(ABS(DETERM)-R2)1050,1050,1060
 1050 DETERM=DETERM*R1
      ISCALE=ISCALE-1
 1060 IF(ABS(PIVOTI)-R1)1090,1070,1070
 1070 PIVOTI=PIVOTI/R1
      ISCALE=ISCALE+1
```

```
      IF(ABS(PIVOTI)-R1)320,1080,1080                                   MATI 730
 1080 PIVOTI=PIVOTI/R1                                                  MATI 740
      ISCALE=ISCALE+1                                                   MATI 750
      GO TO 320                                                         MATI 760
 1090 IF(ABS(PIVOTI)-R2)2000,2000,320                                   MATI 770
 2000 PIVOTI=PIVOTI*R1                                                  MATI 780
      ISCALE=ISCALE-1                                                   MATI 790
      IF(ABS(PIVOTI)-R2)2010,2010,320                                   MATI 800
 2010 PIVOTI=PIVOTI*R1                                                  MATI 810
      ISCALE=ISCALE-1                                                   MATI 820
  320 DETERM=DETERM*PIVOTI                                              MATI 830
C                                                                       MATI 840
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT                                 MATI 850
C                                                                       MATI 860
  330 A(ICOLUM,ICOLUM)=1.0                                              MATI 870
  340 DO 350 L=1,N                                                      MATI 880
  350 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT                                     MATI 890
  355 IF(M) 380,380,360                                                 MATI 900
  360 DO 370 L=1,M                                                      MATI 910
  370 B(ICOLUM,L)=B(ICOLUM,L)/PIVOT                                     MATI 920
C                                                                       MATI 930
C     REDUCE NON-PIVOT ROWS                                             MATI 940
C                                                                       MATI 950
  380 DO 550 L1=1,N                                                     MATI 960
  390 IF(L1-ICOLUM)400,550,400                                          MATI 970
  400 T=A(L1,ICOLUM)                                                    MATI 980
  420 A(L1,ICOLUM)=0.0                                                  MATI 990
  430 DO 450 L=1,N                                                      MATI1000
  450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T                                     MATI1010
  455 IF(M) 550,550,460                                                 MATI1020
  460 DO 500 L=1,M                                                      MATI1030
  500 B(L1,L)=B(L1,L)-B(ICOLUM,L)*T                                     MATI1040
  550 CONTINUE                                                          MATI1050
C                                                                       MATI1060
C     INTERCHANGE COLUMNS                                               MATI1070
  600 DO 710 I=1,N                                                      MATI1080
```

```
C                                                                  MATI1090
  610 L=N+1-I                                                      MATI1100
  620 IF(INDEX(L,1)-INDEX(L,2))630,710,630                         MATI1110
  630 JROW=INDEX(L,1)                                              MATI1120
  640 JCOLUM=INDEX(L,2)                                            MATI1130
  650 DO 705 K=1,N                                                 MATI1140
  660 SWAP=A(K,JROW)                                               MATI1150
  670 A(K,JROW)=A(K,JCOLUM)                                        MATI1160
  700 A(K,JCOLUM)=SWAP                                             MATI1170
  705 CONTINUE                                                     MATI1180
  710 CONTINUE                                                     MATI1190
  740 RETURN                                                       MATI1200
      END                                                          MATI1210
```

```
      SUBROUTINE CAMW (NI,NF)
C - - -  CALCULATION OF ABLATION PRODUCT AVERAGE MOLECULAR WEIGHT - - -
      COMMON/PRCP1/PI(60),RHO(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMON /PRCP4/ NFF,AAMW(60),AT(60)
      DO 10 I=NI,NF
      TT = T(I)
      CALL INTRPL (TT,AT,AAMW,NFF,SCM)
      AMW(I) = SCM
 10   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTRPL(VAR,X,F,IMAX,SUM)
C
C-----THIS PROGRAM PERFORMS LAGRANGIAN INTERPOLATION
C     WITH NON-EQUAL STEP SIZE BETWEEN POINTS
C     F=DEPENDENT VARIABLE
C     X=INDEPENDENT VARIABLE
C     VAR=VALUE OF X FOR WHICH CORRESPONDING VALUE OF
C     F IS DESIRED BY INTERPOLATION
C     IMAX=NUMBER OF POINTS IN ARRAY X OR F
C     SUM=VALUE OF INTERPOLATED DEPENDENT VARIABLE
C     NPTS=NUMBER OF POINTS USED FOR INTERPOLATION
C
      DIMENSION X(60),F(60),XN(180),FN(180)
      NPTS=3
  607 XUP=1.E30
      DO611 I=1,IMAX
      T=VAR-X(I)
      IF(T.GE.0.0)GO TO 609
  608 T=-T
  609 IF(T.GE.XUP)GO TO 611
  610 IP=I
      XUP=T
  611 CONTINUE
      IN=1
      NPP=NPTS+1
      DO618I=1,NPP
      FN(I)=F(IP)
      XN(I)=X(IP)
      IF(IN.GT.0)GO TO 613
  612 IQ=IP-I
      GO TO 615
  613 IQ=IP+I
      IF(IMAX.GE.IQ)GO TO 615
  614 IP=IP-1
      GO TO 618
  615 IF(IQ.GT.0)GO TO 617
```

```
616   IP=IP+1                                        INTR 370
      GO TO 618                                      INTR 380
617   IP=IQ                                          INTR 390
      IN=-IN                                         INTR 400
618   CONTINUE                                       INTR 410
      SOM=0.0                                        INTR 420
      FACT=1.0                                       INTR 430
      DO620 J=1,NPTS                                 INTR 440
      SOM=SOM+FACT*FN(1)                             INTR 450
      DO619 I=J,NPTS                                 INTR 460
      IQ=I-J+1                                       INTR 470
619   FN(IQ)=(FN(IQ+1)-FN(IQ))/(XN(I+1)-XN(IQ))      INTR 480
620   FACT=FACT*(VAR-XN(J))                          INTR 490
      RETURN                                         INTR 500
      END                                            INTR 510
```

```
      BLOCK DATA
      COMMON /FINV/ NHVL,NIHVC,FHVC(12),CJ(9),HVJ(9),ZKZ
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON/GUESS/TG1(60),TG2(60)
      COMMON/PROP1/P1(60),RHO(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMON/PROP2/  MU(60),RM(60), AK(60)
      COMMON/PROP3/CPS(20,60),HS(20,60),CP (60),HM(60)
      COMMON/NUMBER/NSP,NNS,NE,NC
      COMMON/FLSP/LSP(5)
      COMMON/ID/SP(20),EL(5)
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON/WT/SMW(20),AWT(5)
      COMMON /BLOCK1/V1(20),V2(20),V3(20)
      COMMON/BLOCK3/K1(20),K2(20)
      COMMON/EQ1/AI(20), BI(20), CI(20), DI(20), EI(20), FI(20), GI(20),
     X          AII(20),BII(20),CII(20),DII(20),EII(20),FII(20),GII(20)
      COMMON/EQ2/AA(20,5),ICODE(20)
      COMMON/EQ3/IA(20,5)
      REAL K1,K2
      DATA NETA/0/
      DATA RHO /25.1,14.3,8.85,6.50,4.37,3.01,2.49,2.17,1.90,1.67,1.46,
     1          1.29,1.16,1.08,1.03,1.00,44*1.0/
      DATA RM /10.0,7.71,5.89,5.10,4.18,3.54,3.31,3.10,2.83,2.48,2.09,
     1         1.72,1.42,1.22,1.09,1.02,44*1.0/
      DATA TG1 / .1033,.2294,.3531,.4719,.5777,.6531,.6867,.7034,.7145,
     1 .7236,.7321,.7401,.7479,.7554,.7628,.7699,.7769,.7836,.7902,
     2 .7967,.8030,.8092,.8153,.8213,.8272,.8331,.8389,.8447,.8504,
     3 .8562,.8619,.8676,.8734,.8791,.8850,.8908,.8968,.9028,.9089,
     4 .9151,.9215,.9280,.9347,.9417,.9488,.9563,.9641,.9723,.9809,
     5 .9901,10*1.0/
      DATA TG2 / .3325,.3325,.3325,.3325,.3325,.3325,.3325,.3326,.3328,
     1 .3331,.3336,.3344,.3357,.3378,.3408,.3452,.3515,.3601,.3718,
     2 .3873,.4076,.4335,.4665,.5075,.5560,.6054,.6487,.6857,.7161,
     3 .7404,.7595,.7749,.7878,.7993,.8100,.8203,.8302,.8399,.8496,
     4 .8594,.8693,.8797,.8904,.9019,.9142,.9278,.9476,.9609,.9757,
     5 .9877,10*1.0/
```

```
C                                                                       DATA 370
      DATA NSP,NNS,NE,NC/20,0,5,20/                                     DATA 380
      DATA SP/ 'C2  ', 'N2  ', 'O   ', 'N   ', 'O+  ',                  DATA 390
     1         'N+  ', 'E-  ', 'C   ', 'H   ', 'H2  ',                  DATA 400
     2         'CO  ', 'C3-G', 'CN  ', 'C2H ', 'C2H2',                  DATA 410
     3         'C3H ', 'C4H ', 'HCN ', 'C2  ', 'C+  '/                  DATA 420
C                                                                       DATA 430
      DATA CWALL /1.000E-10,2.389E-02,5.966E-08,1.838E-05,1.000E-10,    DATA 440
     1            1.000E-10,1.000E-10,1.573E-03,1.708E-02,3.277E-02,    DATA 450
     2            2.578E-01,1.767E-02,3.105E-03,1.500E-01,8.216E-02,    DATA 460
     3            2.037E-01,1.589E-01,4.710E-02,4.130E-03,1.000E-10/    DATA 470
C                                                                       DATA 480
      DATA SMW/32.000,   28.016,   16.000,   14.008,   16.000,          DATA 490
     1         14.008, 5.486E-4,   12.011,    1.008,    2.016,          DATA 500
     2         28.011,   36.033,   26.019,   25.030,   26.038,          DATA 510
     3         37.041,   49.052,   27.027,   24.022,   12.011/          DATA 520
C                                                                       DATA 530
      DATA V1/0.1693E 01,0.9704E 00,0.1519E 01,0.2534E 00,0.0      ,    DATA 540
     1        0.0       ,0.0       ,0.1997E 01,0.2941E 00,-.7944E-01,   DATA 550
     2        0.2404E 01,0.2019E 01,0.2404E 01,0.2404E 01,0.1396E 01,   DATA 560
     3        0.2019E 01,0.2019E 01,0.1378E 01,0.1931E 01,0.0      /    DATA 570
C                                                                       DATA 580
      DATA V2/0.1496E-02,0.1613E-02,0.1875E-02,0.2206E-02,0.5000E-03,   DATA 590
     1        0.5000E-03,0.5000E-03,0.1772E-02,0.8893E-03,0.7907E-03,   DATA 600
     2        0.1363E-02,0.1179E-02,0.1363E-02,0.1363E-02,0.8423E-03,   DATA 610
     3        0.1179E-02,0.1179E-02,0.9651E-03,0.1393E-02,0.5000E-03/   DATA 620
C                                                                       DATA 630
      DATA V3/-.2276E-07,-.1916E-07,-.2228E-07,-.3737E-07,-.1000E-07,   DATA 640
     1        -.1000E-07,-.1000E-07,-.3378E-07,-.8111E-08,-.8864E-08,   DATA 650
     2        -.2184E-07,-.1655E-07,-.2184E-07,-.2184E-07,-.6939E-08,   DATA 660
     3        -.1655E-07,-.1655E-07,-.9481E-08,-.2575E-07,-.1000E-07/   DATA 670
C                                                                       DATA 680
      DATA  AI/0.3316E 01,0.3221E 01,0.2670E 01,0.2474E 01,0.2491E 01,  DATA 690
     1         0.2727E 01,0.2500E 01,0.2612E 01,0.2500E 01,0.3358E 01,  DATA 700
     2         0.3254E 01,0.4002E 01,0.3411E 01,0.3485E 01,0.3891E 01,  DATA 710
     3         0.3965E 01,0.5874E 01,0.3654E 01,0.4443E 01,0.2609E 01/  DATA 720
```

```
                                                                           DATA 730
C                                                                          DATA 740
      DATA BI/0.1151E-02,0.9878E-03,-.1970E-03,0.9097E-04,0.2762E-04,      DATA 750
     1 -.2820E-03,0.3440E-06,-.2030E-03,-.8243E-06,0.2794E-03,             DATA 760
     2 0.9698E-03,0.3541E-02,0.4897E-03,0.3563E-02,0.5717E-02,             DATA 770
     3 0.6200E-02,0.7403E-02,0.3444E-02,-.2885E-03,-.1393E-03/             DATA 780
C                                                                          DATA 790
      DATA CI/-.3726E-06,-.2907E-06,0.7193E-07,-.7814E-07,-.1881E-07,      DATA 800
     1 0.1105E-06,-.1954E-09,0.1095E-06,0.6421E-09,0.9372E-07,             DATA 810
     2 -.2647E-06,-.1318E-05,0.1005E-06,-.1237E-05,-.1957E-05,             DATA 820
     3 -.2265E-05,-.2729E-05,-.1258E-05,0.3036E-06,0.5959E-07/             DATA 830
C                                                                          DATA 840
      DATA DI/0.6186E-10,0.3938E-10,-.8901E-11,0.2218E-10,0.3807E-11,      DATA 850
     1 -.1551E-10,0.3937E-13,-.1695E-10,-.1720E-12,-.2948E-10,             DATA 860
     2 0.3037E-10,0.2064E-09,-.3473E-10,0.1866E-09,0.2931E-09,             DATA 870
     3 0.3717E-09,0.4437E-09,0.2169E-09,-.6244E-10,-.1037E-10/             DATA 880
C                                                                          DATA 890
      DATA EI/-.3666E-14,-.2000E-14,0.4002E-15,-.1489E-14,-.1028E-15,      DATA 900
     1 0.7847E-15,-.2573E-17,0.8590E-15,0.1457E-16,0.2141E-14,             DATA 910
     2 -.1177E-14,-.1144E-13,0.2361E-14,-.1013E-13,-.1585E-13,             DATA 920
     3 -.2262E-13,-.2637E-13,-.1430E-13,0.3915E-14,0.6345E-15/             DATA 930
C                                                                          DATA 940
      DATA FI/-.1044E 04,-.1043E 04,0.2915E 05,0.5609E 05,0.1879E 06,      DATA 950
     1 0.2254E 06,-.7450E 03,0.8542E 05,0.2547E 05,-.1018E 04,             DATA 960
     2 -.1434E 05,0.9423E 05,0.4745E 05,0.5809E 05,0.2590E 05,             DATA 970
     3 0.6283E 05,0.7605E 05,0.1442E 05,0.9787E 05,0.2168E 06/             DATA 980
C                                                                          DATA 990
      DATA GI/0.5393E 01,0.4326E 01,0.4504E 01,0.4300E 01,0.4424E 01,      DATA1000
     1 0.3645E 01,-.1173E 02,0.4144E 01,-.4612E 00,-.3548E 01,             DATA1010
     2 0.4875E 01,0.2020E 01,0.4746E 01,0.4784E 01,0.6520E 00,             DATA1020
     3 0.3467E 01,-.4010E 01,0.2373E 01,-.1090E 01,0.3709E 01/             DATA1030
C                                                                          DATA1040
      DATA AII/0.3721E 01,0.3727E 01,0.2548E 01,0.2746E 01,0.2944E 01,     DATA1050
     1 0.2499E 01,0.2508E 01,0.2141E 01,0.3934E 01,0.3363E 01,             DATA1060
     2 0.3366E 01,0.2213E 02,0.3473E 01,0.5307E 01,0.6789E 01,             DATA1070
     3 0.3965E 01,0.5874E 01,0.3654E 01,0.4026E 01,0.2528E 01/             DATA1080
C
```

```
      DATA BII/0.4254E-03,0.4684E-03,-.5952E-04,-.3909E-03,-.4108E-03,   DATA1090
     1         -.3725E-05,-.6332E-05,0.3219E-03,-.1776E-02,0.4656E-03,   DATA1100
     2         0.8027E-03,-.1759E-01,0.7337E-03,0.8966E-03,0.1503E-02,   DATA1110
     3         0.6200E-02,0.7403E-02,0.3444E-02,0.4857E-03,0.4869E-05/   DATA1120
C                                                                        DATA1130
      DATA CII/-.2835E-07,-.1140E-06,0.2701E-07,0.1338E-06,0.9156E-07,   DATA1140
     1         0.1147E-07,0.1364E-08,-.5498E-07,0.6013E-06,-.5127E-07,   DATA1150
     2         -.1968E-06,0.5565E-05,-.9088E-07,-.1378E-06,-.2295E-06,   DATA1160
     3         -.2265E-05,-.2729E-05,-.1258E-05,-.7026E-07,-.7026E-08/   DATA1170
C                                                                        DATA1180
      DATA DII/0.6050E-12,0.1154E-10,-.2798E-11,-.1191E-10,-.5848E-11,   DATA1190
     1         -.1102E-11,-.1094E-12,0.3604E-11,-.7819E-10,0.2802E-11,   DATA1200
     2         0.1940E-10,-.6758E-09,0.4847E-11,0.9251E-11,0.1534E-10,   DATA1210
     3         0.3717E-09,0.4437E-09,0.2169E-09,0.4666E-11,0.1134E-11/   DATA1220
C                                                                        DATA1230
      DATA EII/-.5186E-17,-.3293E-15,0.9380E-16,0.3369E-15,0.1190E-15,   DATA1240
     1         0.3078E-16,0.2934E-17,-.5564E-16,0.3482E-14,-.4905E-16,   DATA1250
     2         -.5549E-15,0.2825E-13,-.1018E-15,-.2278E-15,-.3763E-15,   DATA1260
     3         -.2262E-13,-.2637E-13,-.1430E-13,-.1142E-15,-.3476E-16/   DATA1270
C                                                                        DATA1280
      DATA FII/-.1044E 04,-.1043E 04,0.2915E 05,0.5609E 05,0.1879E 06,   DATA1290
     1         0.2254E 06,-.7450E 03,0.8542E 05,0.2547E 05,-.1018E 04,   DATA1300
     2         -.1434E 05,0.9423E 05,0.5420E 05,0.5809E 05,0.2590E 05,   DATA1310
     3         0.6283E 05,0.7605E 05,0.1442E 05,0.9787E 05,0.2168E 06/   DATA1320
C                                                                        DATA1330
      DATA GII/0.3254E 01,0.1294E 01,0.5049E 01,0.2872E 01,0.1750E 01,   DATA1340
     1         0.4950E 01,-.1208E 02,0.6874E 01,-.8598E 01,-.3716E 01,   DATA1350
     2         0.4263E 01,-.1021E 03,0.4152E 01,-.5288E 01,-.1539E 02,   DATA1360
     3         0.3407E 01,-.4010E 01,0.2373E 01,0.1090E 01,0.4139E 01/   DATA1370
C                                                                        DATA1380
      DATA K1/0.1019E 01,0.6541E 00,0.1250E 01,0.1281E 01,0.1000E-04,   DATA1390
     1        0.1000E-04,0.1000E-04,0.2506E 01,0.2496E 01,0.3211E 01,   DATA1400
     2        0.8589E 00,0.6304E 00,0.8589E 00,0.1126E 01,0.1126E 01,   DATA1410
     3        0.6304E 00,0.6304E 00,0.4855E 00,0.8539E 00,0.1000E-04/   DATA1420
C                                                                        DATA1430
      DATA K2/0.4901E-03,0.6457E-03,0.7092E-03,0.8593E-03,0.7350E-03,   DATA1440
```

```
     1          0.7350E-03,0.7350E-03,0.7479E-03,0.5129E-02,0.5344E-02,   DATA1450
     2          0.6233E-03,0.5804E-03,0.6233E-03,0.7439E-03,0.7439E-03,   DATA1460
     3          0.5804E-03,0.5804E-03,0.8714E-03,0.6233E-03,0.7350E-03/   DATA1470
C                                                                         DATA1480
      DATA ICODE/20*0/                                                    DATA1490
C                                                                         DATA1500
      DATA EL/   'C',     'H',     'N',     'O',     'E'    /             DATA1510
      DATA AWT/ 12.011,   1.008,  14.008, 16.000, 5.486E-4  /             DATA1520
C                                                                         DATA1530
      DATA IA/ 0,0,0,0,0,0,0,1,0,0,1,3,1,2,2,3,4,1,2,1,                   DATA1540
     H         0,0,0,0,0,0,0,0,1,2,0,0,0,1,2,1,1,1,0,0,                   DATA1550
     N         0,2,0,1,0,1,0,0,0,0,0,0,1,0,0,0,0,1,0,0,                   DATA1560
     O         2,0,1,0,1,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,                   DATA1570
     E         2,2,1,1,0,0,1,1,0,0,2,3,2,2,2,3,4,2,2,0/                   DATA1580
C                                                                         DATA1590
      DATA LSP/20,9,6,5,7/                                                DATA1600
      DATA NHVL /9/, NIHVC /12/                                           DATA1610
      DATA FHVC /5.0,  6.0,  7.0,  8.0, 9.0,  10.0,  10.8, 11.1,          DATA1620
     1          12.0, 13.4, 14.3, 20.0/                                   DATA1630
      DATA DJ   /0.6,  2.2,  1.5,  1.65, 1.4,  1.0,   1.2,  1.4,          DATA1640
     1           1.0/                                                     DATA1650
      DATA HVJ  /1.3,  2.7,  5.75,  7.57, 9.1, 10.4,  11.4, 12.7,         DATA1660
     1          13.9/                                                     DATA1670
      DATA ZKZ  /7.26E-16/                                                DATA1680
      END                                                                 DATA1690
```

```
      SUBROUTINE PRCPRT(NSP,NI,NF)                                      PROP  10
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * PROP  20
C                                                                       PROP  30
C      SUBROUTINE FOR THE CALCULATICN OF TRANSPORT AND THERMO-          PROP  40
C      DYNAMIC PROPERTIES.                                              PROP  50
C                                        BY D. ESCH                     PROP  60
C                                                                       PROP  70
C      NOMENCLATURE....                                                 PROP  80
C         Y(I)...MOLE FRACTION OF COMPONENT I                           PROP  90
C         C(I,N)...MASS FRACTION OF COMPONENT I AT POINT N              PROP 100
C         RC(N).....DENSITY AT PCINT N.   LBM/ FT**3                    PROP 110
C         TT(N).....TEMPERATURE AT PCINT N. DEG. K                      PROP 120
C         CP(I).....HEAT CAPACITY, CAL/GMOLE-K                          PROP 130
C         CPM(N)....MIXTURE HEAT CAPACITY AT TEMPERATURE, TT(N)         PROP 140
C         H(I)......ENTHALPY CF COMPONENT I, CAL/GMOLE                  PROP 150
C         HM(N).....MIXTURE ENTHALPY AT TEMPERATURE TT(N)               PROP 160
C         VIS(I)....VISCOSITY OF COMPCNENT I, LB/FT-SEC                 PROP 170
C         VISM(N)...MIXTURE VISCOSITY AT TEMPERATURE, TT(N)             PROP 180
C         TC(I).....THERMAL CONDUCTIVITY, CAL/CM-SEC-K                  PROP 190
C         TCM(N)....THERMAL CONDUCTIVITY OF THE MIXTURE AT TT(N)        PROP 200
      COMMON /BLOCK1/V1(20),V2(20),V3(20)                               PROP 210
      COMMON/BLOCK3/K1(20),K2(20)                                       PROP 220
      COMMON/EQ1/AI(20), BI(20), CI(20), DI(20), EI(20), FI(20), GI(20),PROP 230
     X         AII(20),BII(20),CII(20),DII(20),EII(20),FII(20),GII(20)  PROP 240
      COMMON /FRSTRM/ U INF, RINF, LINF2,RAD, RE, LXI, ITM, IEM, NT     PROP 250
      COMMON /NCN/RDZ,MUCZ,RMDZ,AKNF,HNF,CPNF                           PROP 260
      COMMON/PRCP1/PI(60),RC(60),TT(60),AMW(60),C (20,60),CC(5,60)      PROP 270
      COMMON/PRCP2/VISM(60),RM(60),TCM(60)                              PROP 280
      COMMON/PRCP3/CP(20,60),H(20,60),CPM(60),HM(60)                    PROP 290
      COMMON /RH/ DUD,DPHI,ID,RZB,PC,HC,HTOTAL                          PROP 300
      COMMON/WT/SMW(20),AWT(5)                                          PROP 310
      COMMON /YL/ETA(60),YCND(60)                                       PROP 320
      DIMENSICN PHI(20,20),YPHI(20),Y(20),TC(20),VIS(20)                PROP 330
      DIMENSICN SAMW(2)                                                 PROP 340
      REAL  MU,MUCZ                                                     PROP 350
      REAL K1,K2                                                        PROP 360
      DATA R /1.98716/
```

```
C
      R7R = .7608
C AVERAGE ABLATION-AIR PROPERTIES
      IS = NF -9
      ISP = NF+10
      IF(ISP.GE.NT   ) ISP= NT   -1
      IF(IS.LE. 0)   IS = 1
      SAMW(1) = AMW(IS)
      SAMW(2) = AMW(ISP)
      DO 10 I=IS,ISP
      AMW(I) = (SAMW(2)-SAMW(1))*(ETA(I)-ETA(IS))/(ETA(ISP)-ETA(IS))
     1  + SAMW(1)
   10 CONTINUE
      DO 15 I= NF,ISP
      T1 = TT(I)*TD
      RO(I) = R7R *PI(I)*AMW(I)/T1
   15 CONTINUE
      DO2CON=N1,NF
      T1=TT(N) *TD
      RO(N) = R7R *PI(N)*AMW(N)/T1
      T2=T1*T1
      T3=T2*T1
      T4=T3*T1
      T5=T4*T1
      DO9CI=1,NSP
      IF(T1.GT.6000.)GOTO50
      CP(I,N)=( AI(I)+ BI(I)*T1+ CI(I)*T2+ DI(I)*T3+ EI(I)*T4)*R
      H(I,N)=( AI(I)*T1+ BI(I)*T2/2.+ CI(I)*T3/3.+ DI(I)*T4/4.
     X                + EI(I)*T5/5.+ FI(I))*R
      GOTO60
   50 CP(I,N)=(AII(I)+BII(I)*T1+CII(I)*T2+DII(I)*T3+EII(I)*T4)*R
      H(I,N)=(AII(I)*T1+BII(I)*T2/2.+CII(I)*T3/3.+DII(I)*T4/4.
     X                +EII(I)*T5/5.+FII(I))*R
   60 Y(I)=C(I,N)*AMW(N)/SMW(I)
      VIS(I)=(V1(I) + V2(I)*T1 + V3(I)*T2)*1.0E-05
      TC(I)=(K1(I)+K2(I)*T1)*1.0E-05
```

```
 90   CONTINUE
C
C-----CALCULATE PHI(I,J) PARAMETERS FOR MIXTURE PROPERTIES....
C
      DO95I=1,NSP
      DO95J=1,NSP
      VIS12=SQRT(VIS(I)/VIS(J))
      SMW14=(SMW(J)/SMW(I))**.25
      PHI(I,J)=.354*((1.+VIS12*SMW14)**2)/SQRT(1.+SMW(I)/SMW(J))
  95  CONTINUE
C
C-----CALCUALTION OF MIXTURE PROPERTIES...
C
      DO100I=1,NSP
      YPHI(I)=0.0
      DO100J=1,NSP
 100  YPHI(I)=YPHI(I) + Y(J)*PHI(I,J)
C     VISM(N)=0.0
C     CPM(N)=0.0
      HM(N)=0.0
      TCF=0.0
      CPF=0.0
      CPR=0.0
      SUMY=0.0
      DYDT = 0.0
      DO120I=1,NSP
      IF(Y(I).LT.1.E-5) GO TO 120
C     CALL GRAD(I,NT,T1,DYDT)
      HM(N)=HM(N)+Y(I)*H(I,N)
      SUMY=SUMY+Y(I)
      CPF=CPF + Y(I)*CP(I,N)
      CPR=CPR + AMW(N)*H(I,N)*DYDT
C     VISM(N)=VISM(N)+Y(I)*VIS(I)/YPHI(I)
      TCF=TCF + Y(I)*TC(I)/YPHI(I)
C     CPM(N)=CPF + CPR
C     TCM(N)=TCF
```

```
C     PR=VISM(N)*CPM(N)*14.88/(TCM(N)*AMW(N))                          PROP1090
  120 CONTINUE                                                           PROP1100
  200 CONTINUE                                                           PROP1110
C----- NONDIMENSIONALIZE QUANTITIES -----                                PROP1120
C                                                                        PROP1130
      DO 250 I=NI,NF                                                     PROP1140
C     VISM(I) = VISM(I)/MUDZ                                             PROP1150
C     TCM(I) = TCM(I)*AKNF/13825.7                                       PROP1160
      RO(I) = RC(I)/(RDZ*32.174)                                         PROP1170
C     CPM(I)=CPM(I)*CPNF/AMW(I)                                          PROP1180
      DO 250 K=1,NSP                                                     PROP1190
      CP(K,I) = CP(K,I)*CPNF/SMW(K)                                      PROP1200
      H(K,I) = H(K,I)*HNF/(1.8*SMW(K))                                   PROP1210
  250 CONTINUE                                                           PROP1220
      NF1 = NF +1                                                        PROP1230
      DO 300 I=NF1,ISP                                                   PROP1240
      RO(I) = RC(I)/(RDZ*32.174)                                         PROP1250
  300 CONTINUE                                                           PROP1260
      RETURN                                                             PROP1270
      END                                                                PROP1280
```

```
      SUBROUTINE GAS (KODE )
C
C     **   THERMODYNAMIC AND TRANSPORT PROPERTIES OF AIR **
C     **  REFERENCE NASA TR R-50 **
C
C  THE FOLLOWING PROPERTIES ARE CALCULATED
C                 TEMPERATURE AT WHICH PROPERTIES ARE WANTED (T) IN DEG R
C                 PRESSURE AT WHICH PROPERTIES ARE WANTED (P) IN LB/IN**2
C                 RATIO OF SPECIFIC HEATS (GAMMA) IN DIMENSIONLESS
C                 SPECIFIC HEAT AT CONSTANT PRESSURE (CP) IN BTU/LB-DEG R
C                 ABSOLUTE VISCOSITY (V) IN LB/FT-SEC
C                 PRANDTL NUMBER (PR) IN DIMENSIONLESS
C                 THERMAL CONDUCTIVITY (XK) IN BTU/FT-SEC-DEG R
C                 PRESSURE (P) IN ATMOSPHERES
C                 DENSITY (DEN) IN LB/FT**3
C                  ENTHALPY (H) IN BTU/LB
C                  ENTROPY (S) IN BTU/LB-DEG R
C                  COMPRESSIBILITY (Z) IN DIMENSIONLESS
C                  SPEED OF SOUND (SOS) IN FT/SEC
C                  SPECIFIC HEAT AT CONSTANT VOLUMN (CV) IN BTU/LB-DEG R
C                  ENTROPY (S) IN FT**2/SEC**2
C                  VELOCITY (VEL) IN FT/SEC
C                  PRESSURE (P) IN LBS/FT**2
C                  MACH NUMBER (M) IN DIMENSIONLESS
C
C
C NOMENCLATURE    1=OXYGEN MOLECULES, 2=NITROGEN MOLECULES, 3=OXYGEN ATMOS
C                 4=NITROGEN ATMOS, 5=OXYGEN IONS, 6=NITROGEN IONS
C                 7=ELECTRONS
C
C
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /NCN/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/PRCP1/PI(60),RHC(60),TI(60),AMW(60),C (20,60),CC(5,60)
      COMMON/PROP2/  MU(60),RM(60), AK(60)
      COMMON/PRCP3/CPS(20,60),HS(20,60),CPT(60),HM(60)
```

```
      COMMON /RH/ DUD,DPHI,TD,RZB,PD,HD,HTOTAL
      COMMON/WALL/RVW,PRW,TWCLD,FLUX(20),CWALL(20),ECWALL(5)
      REAL  MU,MUDZ
      LOGICAL MCONV,GCONV,SCONV
      DATA GASC /49721.7/
C
C
      DO 2000 I=KODE,NETA
      T = TI(I) * TC
      P = PI(I)
C
C THE FOLLOWING PART OF PROGRAM USES PRESSURE IN ATMOSPHERES
C AND TEMPERATURE IN DEG K
C
      ITER=0
C
C     **  TEMPERATURE - ENTHALPY ITERATION  **
C
  900 CONTINUE
      ITER=ITER+1
      IF(T.LT.100.) T=100.
      A1=11390./T
      A2=18990./T
      A3=2270./T
      A4=3390./T
      A5=228./T
      A6=326./T
      A7=22800./T
      A8=48600./T
      A9=27700./T
      A10=41500./T
      A11=38600./T
      A12=58200./T
      A13=70.6/T
      A14=188.9/T
      A15=22000./T
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```
      A16=47000./T                                                      GAS  730
      A17=67900./T                                                      GAS  740
      A18=2270./(4.*T)                                                  GAS  750
      A19=TANH(A18)                                                     GAS  760
      A20=3390./(4.*T)                                                  GAS  770
      A21=TANH(A20)                                                     GAS  780
      TT=1./T                                                           GAS  790
      TSQ=T**2                                                          GAS  800
      TSQRT=T**.5                                                       GAS  810
      A22=112.2222/T                                                    GAS  820
      A23=T/59000.                                                      GAS  830
      A24=T/113200.                                                     GAS  840
      A25=T/75400.                                                      GAS  850
      AA1=EXP(-A1)                                                      GAS  860
      AA2=EXP(-A2)                                                      GAS  870
      AA3=EXP(A3)                                                       GAS  880
      AA4=EXP(A4)                                                       GAS  890
      AA5=EXP(-A5)                                                      GAS  900
      AA6=EXP(-A6)                                                      GAS  910
      AA7=EXP(-A7)                                                      GAS  920
      AA8=EXP(-A8)                                                      GAS  930
      AA9=EXP(-A9)                                                      GAS  940
      AA10=EXP(-A10)                                                    GAS  950
      AA11=EXP(-A11)                                                    GAS  960
      AA12=EXP(-A12)                                                    GAS  970
      AA13=EXP(-A13)                                                    GAS  980
      AA14=EXP(-A14)                                                    GAS  990
      AA15=EXP(-A15)                                                    GAS 1000
      AA16=EXP(-A16)                                                    GAS 1010
      AA17=EXP(-A17)                                                    GAS 1020
C   CALCULATING ENERGIES PER COMPONENT OF GAS MIXTURE ABOVE             GAS 1030
C   REFERENCE ENERGIES.                                                 GAS 1040
      E1=2.5+((2.*AA1*A1+AA2*A2)/(3.+2.*AA1+AA2))+(A3/(AA3-1.))         GAS 1050
      ET=2.5+ (A4/(AA4-1.))                                             GAS 1060
      E3=1.5+((3.*AA5*A5+AA6*A6+5.*AA7*A7+AA8*A8)/(5.+3.*AA5+AA6+5.*AA7+GAS 1070
     1AA8))                                                             GAS 1080
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      E4=1.5+((10.* AA9*A9+6.*AA10*A10)/(4.+10.*AA9+6.*AA10))           GAS 1090
      E5=1.5+((10.*AA11*A11+6.*AA12*A12)/(4.+10.*AA11+6.*AA12))         GAS 1100
      E6=1.5+((3.*AA13*A13+5.*AA14*A14+5.*AA15*A15+AA16*A16+5.*AA17*A17)GAS 1110
     1/(1.+3.*AA13+5.*AA14+5.*AA15+AA16+5.*AA17))                       GAS 1120
      E7=1.5                                                            GAS 1130
C TOTAL ENERGY PER COMPONENT OF GAS MIXTURE                             GAS 1140
      EN1=E1                                                            GAS 1150
      EN2=ET                                                            GAS 1160
      EN3=E3+29500./T                                                   GAS 1170
      EN4=E4+56600./T                                                   GAS 1180
      EN5=E5+187500./T                                                  GAS 1190
      EN6=E6+225400./T                                                  GAS 1200
      EN7=E7                                                            GAS 1210
C LOGS OF PARTITION FUNCTIONS                                           GAS 1220
      TL1=ALOG(T)*3.5                                                   GAS 1230
      TL2=ALOG(T)*2.5                                                   GAS 1240
      EQ1=TL1+.11+ALOG((3.+2.*AA1+AA2)/(1.-(1.0/AA3)))                  GAS 1250
      EQ2=TL1-.42-ALOG((1.-(1.0/AA4)))                                  GAS 1260
      EQ3=TL2+.5+ALOG((5.+3.*AA5+AA6+5.*AA7+AA8))                       GAS 1270
      EQ4=TL2+.3+ALOG((4.+10.*AA9+6.*AA10))                             GAS 1280
      EQ5=TL2+.5+ALOG((4.+10.*AA11+6.*AA12))                            GAS 1290
      EQ6=TL2+.3+ALOG((1.+3.*AA13+5.*AA14+5.*AA15+AA16+5.*AA17))        GAS 1300
      EQ7=TL2-14.24                                                     GAS 1310
C EQUILIBRIUM CONSTANS FOR CHEMICAL REACTIONS                           GAS 1320
      EK1=-59000./T+2.*EQ3-EQ1                                          GAS 1330
      EK2=-113200./T+2.*EQ4-EQ2                                         GAS 1340
      EK3=-158000./T+EQ5+EQ7-EQ3                                        GAS 1350
      EK4=-168800./T+EQ6+EQ7-EQ4                                        GAS 1360
      CCC=-79.9                                                         GAS 1370
      IF(EK1.LE.CCC) EK1=-79.9                                          GAS 1380
      IF(EK2.LE.CCC) EK2=-79.9                                          GAS 1390
      IF(EK3.LE.CCC) EK3=-79.9                                          GAS 1400
      IF(EK4.LE.CCC) EK4=-79.9                                          GAS 1410
      XK1=EXP(EK1)                                                      GAS 1420
      XK2=EXP(EK2)                                                      GAS 1430
      XK3=EXP(EK3)                                                      GAS 1440
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```
      XK4=EXP(EK4)                                                      GAS 1450
      XK34=.2*XK3+.8*XK4                                                GAS 1460
      EE1=(-0.8+(.64+.8*(1.+((4.*P)/XK1)))**0.5)/(2.*(1.+4.*P/XK1))     GAS 1470
      EE2=(-0.4+(.16+3.84*(1.+(4.*P)/(XK2)))**0.5)/(2.*(1.+4.*P/XK2))   GAS 1480
      EE3= 1./(( 1.+P/XK34)**.5)                                        GAS 1490
C COMPRESSIBILITY (Z) DIMENSIONLESS                                     GAS 1500
      Z=1.+EE1+EE2+2.*EE3                                               GAS 1510
C COMPONENT MOL FRACTIONS IN AIR                                        GAS 1520
      X1=(.2-EE1)/Z                                                     GAS 1530
      X2=(.8-EE2)/Z                                                     GAS 1540
      X3=(2.*EE1-.4*EE3)/Z                                              GAS 1550
      X4=(2.*EE2-1.6*EE3)/Z                                             GAS 1560
      X5= .4*EE3/Z                                                      GAS 1570
      X6= 1.6*EE3/Z                                                     GAS 1580
      X7= 2.*EE3/Z                                                      GAS 1590
      IF(X1.LE.0.)  X1=1.E-20                                           GAS 1600
      IF(X2.LE.0.)  X2=1.E-20                                           GAS 1610
      IF(X3.LE.0.)  X3=1.E-20                                           GAS 1620
      IF(X4.LE.0.)  X4=1.E-20                                           GAS 1630
      IF(X5.LE.0.)  X5=1.E-20                                           GAS 1640
      IF(X6.LE.0.)  X6=1.E-20                                           GAS 1650
      IF(X7.LE.0.)  X7=1.E-20                                           GAS 1660
C ENERGY PER MOL OF INITIALLY UNDISSOCIATED AIR-DIMENSIONLESS           GAS 1670
      ER= Z*(X1*EN1+X2*EN2+X3*EN3+X4*EN4+X5*EN5+X6*EN6+X7*EN7)          GAS 1680
C ENTHALPY PER INITIAL MOL OF AIR-DIMENSIONLESS                         GAS 1690
      HR=ER+Z                                                           GAS 1700
C ENTHALPY PER INITIAL MOL OF AIR (H) IN BTU/LB                         GAS 1710
      H=HR*T*.12348                                                     GAS 1720
      IF(KODE.LT.NETA) GO TO 1000                                       GAS 1730
      HRATO=.5*(H-HD)/H                                                 GAS 1740
      AHR  = ABS( HRATO )                                               GAS 1750
      IF(AHR .LE. 0.0010) GO TO 999                                     GAS 1760
      IF(ITER .GT.1) GO TO 203                                          GAS 1770
      TP=T                                                              GAS 1780
      HP=HRATO                                                          GAS 1790
      T = T *(1. - HRATO )                                              GAS 1800
```

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                                                                          GAS 1810
      IF(ITER .LT. 15) GO TO 900                                          GAS 1820
  203 CONTINUE                                                            GAS 1830
      TS=T*(1.0-HRATO)                                                    GAS 1840
      IF(HRATO*HP .LT.0.0) TS=.5*(T+TP)                                   GAS 1850
      TP=T                                                                GAS 1860
      T=TS                                                                GAS 1870
      HP=HRATO                                                            GAS 1880
      IF(ITER .LT. 15) GO TO 900                                          GAS 1890
      WRITE(6,200) T,H,HT                                                 GAS 1900
  200 FORMAT(39H1TEMPERATURE-ENTHALPY DID NOT CONVERGE /3E15.6)           GAS 1910
C     CALL OUTPUT(4)                                                      GAS 1920
      STOP                                                                GAS 1930
  999 CONTINUE                                                            GAS 1940
      TD = T                                                              GAS 1950
C                                                                         GAS 1960
 1000 CONTINUE                                                            GAS 1970
C ENTROPY PER INITIAL MOL OF AIR-DIMENSIONLESS                            GAS 1980
      D1=E01+E1+1.                                                        GAS 1990
      D2=E02+ET+1.                                                        GAS 2000
      D3=E03+E3+1.                                                        GAS 2010
      D4=E04+E4+1.                                                        GAS 2020
      D5=E05+E5+1.                                                        GAS 2030
      D6=E06+E6+1.                                                        GAS 2040
      D7=E07+E7+1.                                                        GAS 2050
C TOTAL ENTROPY                                                           GAS 2060
      SR=Z*(X1*D1+X2*D2+X3*D3+X4*D4+X5*D5+X6*D6+X7*D7)-Z*(X1*ALOG(X1) + GAS 2070
     1X2*ALOG(X2)+X3*ALOG(X3)+X4*ALOG(X4)+X5*ALOG(X5)+X6*ALOG(X6)+X7*     GAS 2080
     2ALOG(X7))-Z*ALOG(P)                                                 GAS 2090
C ENTROPY PER INITIAL MOL OF AIR (S) IN BTU/LB-DEG R                      GAS 2100
      S    =SR*0.0686                                                     GAS 2110
C SPECIFIC HEAT AT CONSTANT VOLUME-CV                                     GAS 2120
      FF1=3.+2.*AA1+AA2                                                   GAS 2130
      CV1=2.5+((2.*AA1*A1*A1+AA2*A2*A2)/FF1)-(((2.*AA1*A1+AA2*A2)/FF1)**GAS 2140
     12.)+((.25*A3*A3)/(((2.*A19)/(1.-A19*A19))**2))                      GAS 2150
      CV2=2.5+((.25*A4*A4)/(((2.*A21)/(1.-A21*A21))**2))                  GAS 2160
      CV3=1.5+((3.*AA5*A5*A5+AA6*A6*A6+5.*AA7*A7*A7+AA8*A8*A8)/(5.+3.*AAGAS
```

```
15+AA6+5.*AA7+AA8))-((E3-1.5)**2.)
 CV4=1.5+((10.*AA9*A9*A9+6.*AA1C*A1C*A10)/(4.+10.*AA9+6.*AA10))
1-((E4-1.5)**2.)
 CV5=1.5+((10.*AA11*A11*A11+6.*AA12*A12*A12)/(4.+10.*AA11+6.*AA12))
1-((E5-1.5)**2.)
 CV6=1.5+((3.*AA13*A13*A13+5.*AA14*A14*A14+5.*AA15*A15*A15+AA16*A16
1*A16+5.*AA17*A17**2)/(1.+3.*AA13+5.*AA14+5.*AA15+AA16+5.*AA17))-((
2E6-1.5)**2.)
 CV7=1.5
C LOGARITHMIC DERIVATIVES
 CK1=TT*(59000./T+2.*E3-E1)
 CK2=TT*(113200./T+2.*E4-ET)
 CK3=TT*(158000./T+E5+E7-E3)
 CK4=TT*(168800./T+E6+E7-E4)
 CK34=.2*CK3+.8*CK4
 PK1= CK1+TT
 PK2= CK2+TT
 PK3= CK3+TT
 PK4= CK4+TT
 PK34=0.2*PK3+0.8*PK4
C PARTIAL DERIVATIVES REQUIRED FOR CP
 DE1P=(PK1*EE1*(1.+EE1)*(.2-EE1))/(.8*(.5-EE1))
 DE2P=(PK2*EE2*(1.2+EE2)*(.8-EE2))/(.4*(4.8-EE2))
 DE3P=.5*PK34*EE3*(1.-EE3**2)
 DZX1P=-DE1P
 DZX2P=-DE2P
 DZX3P=2.*DE1P - .4*DE3P
 DZX4P=2.*DE2P-1.6*DE3P
 DZX5P=.4*DE3P
 DZX6P=1.6*DE3P
 DZX7P=2.* DE3P
C EQUATION FOR SPECIFIC HEAT AT CONSTANT PRESSURE
 CPF=Z*(X1*(CV1+1.)+X2*(CV2+1.)+X3*(CV3+1.)+X4*(CV4+1.)+X5*(CV5+1.
1)+X6*(CV6+1.)+X7*(CV7+1.))
 CPR = CPF +              T*(DZX1P*(EN1+1.)+DZX2P*(EN2+1.)+DZX3P*(E
3N3+1.)+DZX4P*(EN4+1.)+DZX5P*(EN5+1.)+DZX6P*(EN6+1.)+DZX7P*(EN7+1.)
```

```
     4)
      CPF = CPR
C SPECIFIC HEAT AT CONSTANT  PRESSURE (CP) IN BTU/LB-DEG R
      CP=CPR*.0686
      CPF = CPF*.C686
C DENSITY (DEN) IN LB/FT**3
      DEN=22.C3703*P/(Z*T)
C **TRANSPCRT PROPERTIES**
C COLLISION CROSS SECTICNS
      S2=31.4*1.E-16*(1.+(112./T))
      SI2=(S2/3.1415927)**.5
      SI4=(1.11676-(.C149C* ALOG(1.-(1.-A23) **.5))-(.23654* ALOG
     1(1.-(1.-A24)**.5))-(.11582* ALCG(1.-(1.-A25)**.5)))*1.0E-8
      S4=3.1415927*(SI4)**2
      SI24=(SI2+SI4)/2.
      S24=3.1415927*(SI24)**2
      S47=9.4C*1.CE-14/TSQRT
      FI=ALOG(1.C42*1.0E-7*TSQ*(P*X7 )**(-.5))
      S7=8.55644*1.CE-6*(1./TSQ)*FI
      SIP4=(1.11676-(.C149*ALOG(1.-(1.-2.*A23)**.5))-(.23654*ALOG(1.-(1.
     1-2.*A24)**.5))-(.11582* ALCG(1.-(1.-2.*A25)**.5)))*1.0E-8
      SP4=3.145927*(SIP4)**2
      SIP24=(SI2+SIP4)/2.
      SP24=3.145927*SIP24**2
C COMPCNENT MOL FRACTIONS FOR INDEPENDENT REACTICNS
      F1=1.+EE1
      F2=1.2+EE2
      F3=1.+EE3
      X1OD=(.2-EE1)/F1
      X2OD=.8/F1
      X3OD=2.*EE1/F1
      X2ND=(.8-EE2)/F2
      X3ND=.4/F2
      X4ND=2.*EE2/F2
      X4I=(1.-EE3)/F3
      X6I=EE3/F3
```

```
C MEAN FREE PATH RATIOS
      SS1=S24/S2
      SS2=S4/S2
      SS3=S7/S2
      SS4=S47/S2
      FP1OD=X1OD+X2OD*.9660918 +X3OD*SS1*.8164966
      FP2OD=X1OD*1.032796+X2OD+X3OD*SS1*.8528029
      FP3OD=X1OD*1.154701*SS1+X2ND*SS1*1.128152+X3OD*SS2
      FP2ND=X2ND+X4ND*SS1*.8164966+X3ND*SS1*.8528029
      FP3ND=X2ND*SS1*1.128152+X4ND*SS2*.9660918+X3ND*SS2
      FP4ND=X2ND*SS1*1.154701+X4ND*SS2+X3ND*SS2*1.032796
      FP4I=X4I*SS2+X6I*SS2
      FP6I=X4I*SS2+X6I*SS3
      FP7I=X4I*SS4*1.414186+X6I*SS3*1.414186+X6I*SS3
C VISCOSITIES OF THE COMPONENTS FOR THE DIFFERENT REACTIONS
      V1OD=1.054093*X1OD*1./FP1OD
      V2OD=.9860133*X2OD*1./FP2OD
      V3OD=.745356*X3OD*1./FP3OD
      V2ND=.9860133*X2ND*1./FP2ND
      V3ND=.745356*X3ND*1./FP3ND
      V4ND=.6972167*X4ND*1./FP4ND
      V4I=.6972167*X4I*1./FP4I
      V6I=.6972167*X6I*1./FP6I
      V7I=.4367848*1.0E-2*X6I*1./FP7I
      VROD=V1OD+V2OD+V3OD
      VRND=V2ND+V3ND+V4ND
      VRI=V4I+V6I+V7I
      F4=EE2/(.2-EE1+EE2)
      F5=2.*EE3/(.8-EE2+2.*EE3)
      VR=VROD+(F4*(VRND-VROD))+(F5*(VRI-VRND))
C TOTAL VISCOSITY (V) IN LB/FT-SEC
      V=VR*.9841838*1.0E-6*TSQRT/(1.+A22)
C CONDUCTIVITY DUE TO MOLECULAR COLLISIONS FOR DIFFERENT REACTIONS
      G1=.2105263*CV1+.4736842
      G2=.2105263*CV2+.4736842
      G3=.2105263*CV3+.4736842
```

```
      G4=.2105363*CV4+.4736842
      G5=.2105363*CV6+.4736842
      G6=.2105363*CV7+.4736842
      XKNOD=(V1OD*.9*G1)+(V2OD*1.028571*G2)+(V3OD*1.8*G3)
      XKNND=(V2ND*1.028571*G2)+(V3ND*1.8*G3)+(V4ND*2.057143*G4)
      XKNI=(V4I*2.057143*G4)+(V6I*2.057143*G5)+(V7I*52416.0*G6)
      XKN=XKNOD+(F4*(XKNND-XKNOD))+(F5*(XKNI-XKNND))
C CONDUCTIVITY DUE TO CHECMICAL REACTIONS FOR THE DIFFERENT REACTIONS
      XKROD=(.178637*(T*PK1)**2)/((SP24/(1.732051*S2))*(((X3OD+2.*X1OD)
     1**2)/(X3OD*X1OD)+(4.*X2OD/X3OD))+(X2OD/(1.414214*X1OD)))
      XKRND=(.178637*(T*PK2)**2)/((SP24/(1.732051*S2))*((((X4ND+2.*X2ND)
     1**2)/(X4ND*X2ND))+(X3ND/X2ND)) +(SP4*2.*X3ND/(S2*X4ND)))
      XKRI=(.178637*(T*PK34)**2)/(((.5*SP4/S2)+(.4347826*1.0E-2*S47/S2))
     1*((X4I+X6I)**2)/(X4I*X6I))
      XKOD=XKNOD+XKROD
      XKND=XKNND+XKRND
      XKI=XKNI+XKRI
      XKR=XKOD+(F4*(XKND-XKOD))+(F5*(XKI-XKND))
C TOTAL THERMAL CONDUCTIVITY (XK) IN BTU/FT-SEC-DEG R
      XK=XKR*((.3206522*1.0E-6*TSQRT)/(1.+A22))
C PRANDTL NUMBER (PR) DIMENSIONLESS
      PRN = .2105263 * CPR * VR / XKR
      IF(I.EQ. 1) PRW = PRN
C FORM REQUIRED BY CALL STATEMENT
C
C      **   RHO UNITS SLUGS/FT**3
C      **   MU UNITS LBM/FT-SEC
C      **   RM UNITS LBF**2 SEC**3/FT**6
C
      MU (I) = V
      RHO(I)=DEN/32.174
      RM(I)=RHO(I)*MU(I  )/32.174
      AK(I) = XK
      CPT(I) = CPF
C *** CALCULATE  THE MEAN MOLECULAR WT. ***
      REAL = 25050.*S     *Z / SR
```

```
      AMW(I)= GASC / REAL                                              GAS 3610
C MASS FRACTIONS                                                       GAS 3620
      C(1,I) = X1     *32.00/AMW(I)                                    GAS 3630
      C(2,I) = X2     *28.00/AMW(I)                                    GAS 3640
      C(3,I) = X3     *16.00/AMW(I)                                    GAS 3650
      C(4,I) = X4     *14.00/AMW(I)                                    GAS 3660
      C(5,I) = X5     *16.00/AMW(I)                                    GAS 3670
      C(6,I) = X6     *14.00/AMW(I)                                    GAS 3680
      C(7,I) = X7     /(1820.*AMW(I))                                  GAS 3690
C SPECIES ENTHALPY PER INITIAL MOLE OF AIR IN BTU/LB OF I              GAS 3700
      HS(1,I) = (Z*X1*EN1/C(1,I) +Z)*T*.12348                          GAS 3710
      HS(2,I) = (Z*X2*EN2/C(2,I) +Z)*T*.12348                          GAS 3720
      HS(3,I) = (Z*X3*EN3/C(3,I) +Z)*T*.12348                          GAS 3730
      HS(4,I) = (Z*X4*EN4/C(4,I) +Z)*T*.12348                          GAS 3740
      HS(5,I) = (Z*X5*EN5/C(5,I) +Z)*T*.12348                          GAS 3750
      HS(6,I) = (Z*X6*EN6/C(6,I) +Z)*T*.12348                          GAS 3760
      HS(7,I) = (Z*X7*EN7/C(7,I) +Z)*T*.12348                          GAS 3770
 2000 CONTINUE                                                         GAS 3780
      RDZ= RHO(NETA)                                                   GAS 3790
      MUDZ= MU(NETA)                                                   GAS 3800
      RMDZ= RM(NETA)                                                   GAS 3810
C                                                                      GAS 3820
C                                                                      GAS 3830
      DO 40 I=KODE,NETA                                                GAS 3840
C                                                                      GAS 3850
C     **  NONDIMENSIONALIZE  RHO  AND  MU  **                          GAS 3860
C                                                                      GAS 3870
      RHO(I) = RHO(I)/RDZ                                              GAS 3880
      MU(I) = MU(I)/MUDZ                                               GAS 3890
      RM(I) =RM(I)/RMDZ                                                GAS 3900
      AK(I) = AK(I)*AKNF                                               GAS 3910
      CPT(I) = CPT(I)*CPNF                                             GAS 3920
C NONDIMENSIONAL SPECIES ENTHALPY                                      GAS 3930
      HS(1,I) = HS(1,I)*HNF                                            GAS 3940
      HS(2,I) = HS(2,I)*HNF                                            GAS 3950
      HS(3,I) = HS(3,I)*HNF                                            GAS 3960
```

```
      HS(4.I) = HS(4,I)*HNF                                             GAS 3970
      HS(5.I) = HS(5,I)*HNF                                             GAS 3980
      HS(6.I) = HS(6,I)*HNF                                             GAS 3990
      HS(7.I) = HS(7,I)*HNF                                             GAS 4000
C                                                                       GAS 4010
C                                                                       GAS 4020
   40 CONTINUE                                                          GAS 4030
  100 FORMAT(1X,9E14.6)                                                 GAS 4040
      RETURN                                                            GAS 4050
      END                                                               GAS 4060
```

```
      SUBROUTINE TRID (M)
C**** TRID --TRIDIAGONAL EQUATION SOLVER  OBTAINED FROM CONTE P-184 ***
C      SUBROUTINE SOLVES AX = B FOR THE VECTOR X (WHERE A IS TRIDIAGONAL
C      M = ORDER OF SYSTEM
C      SUP = SUPER DIAGONAL OF A
C      SUB = SUB DIAGONAL OF A
C      DIAG = MAIN DIAGONAL OF A
C      B = CONSTANT VECTOR
C      SUP AND DIAG ARE DESTROYED
C      SOLUTION VECTOR IS RETURNED IN B
C
      COMMON/VECTOR/ SUB(60),DIAG(60),SUP(60),B(60)
C
      N = M
      NN = N -1
      SUP(1) = SUP(1)/DIAG(1)
      B(1) = B(1)/DIAG(1)
      DO 10 I=2,N
      II = I -1
C------DECOMPOSE A TO FORM A = LU WHERE L IS LOWER TRIANGULAR,
C       AND U IS UPPER TRIANGULAR ---------
      DIAG(I) = DIAG(I) - SUP(II)*SUB(II)
      IF(I .EQ.  N) GO TO 10
      SUP(I) = SUP(I) / DIAG(I)
C------COMPUTE Z WHERE LZ = B
   10 B(I) = (B(I) - SUB(II) *B(II))/ DIAG(I)
C------COMPUTE X BY BACK SUBSTITUTION WHERE UX = Z
      DO 20 K =1,NN
      I = N - K
   20 B(I) = B(I) -SUP(I) *B(I+1)
      RETURN
      END
```

```
      SUBROUTINE EFLUX
C - - -  THIS SUBROUTINE COMPUTES THE RADIATIVE FLUX DIVERGENCE OF AIR
C          USING CORRELATIONS OF ENGEL AND SPRADLEY (JSR VOL 6,JUNE 69)
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /RH/ DLD,DPHI,TD,RZB,PC,HC,HTOTAL
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON/PRCP1/PI(60),RHO(60), T(60),AMW(60),C (20,60),CC(5,60)
      DO 100 I=1,NETA
      PL = ALOG10(PI(I) )
      TSI= T(I)*TD
      TS = 1100. * PL +13800.
      IF (TS -TSI ) 300,200,200
 200  EP = 10.**(.0005 *TSI  +1.15*PL -3.15 )
      GO TO 350
 300  EP = 10.**(1.875 *PL + 3.903)
C   **** EP  HAS UNITS OF WATTS/CM**3    ***
C
 350  E(I) =(EP*R/( RINF      *UINF2 *U INF) )* 20866.0
 400  E(I) =E(I) *RZB
C
C   **** E IS NONDIMENSIONAL   ***
C
 100   CONTINUE
       RETURN
       END
```

```
      SUBROUTINE OUTPUT(N)
C
C
C     **  ROUTINE TO PRINT SHOCK LAYER SOLUTION   **
C
C
      COMMON/ID/SP(20),EL(5)
      COMMON /CONV/ FPRCT,TPRCT,CDAMP,TDAMP,PDTIL
      COMMON /DEL/ DELTA,DTIL,DTILS
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /MAIN/KEEP,MAXE,MAXN,MAXD,IDEBUG,MCONV,ECONV,DCONV,LT,IAB
      COMMON /NON/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/NUMBER/NSP,NNS,NE,NC
      COMMON/PROP1/PI(60),RHO(60), T(60),AMW(60),C (20,60),EC(5,60)
      COMMON/PROP2/  MU(60),RM(60), AK(60)
      COMMON/PROP3/CPS(20,60),HS(20,60),CP (60),HM(60)
      COMMON /RFLUX/ E(60),IRAD,ITYPE
      COMMON /RH/ DLD,DPHI,TD,RZB,PD,HD,HTOTAL
      COMMON /SFLUX/ GRI(3)
      COMMON/VECTOR/ CA(60),CB(60),CC(60),B(60)
      COMMON /VEL/ F(60),FC(60),Z(60),V(60)
      COMMON/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON /YE/ETA(60),YOND(60)
      DIMENSION RCUT(60),DQR(30)
      REAL [illegible]MUDZ
      DAT[illegible]1/'WALL'/ ,HEAD2/'    '/,HEAD3/'SHOC'/
C
C
C     [illegible] RADIATION FLUX IF UNCOUPLED PROBLEM   **
      IF([illegible] C) GO TO 20
      IF([illegible]EQ. 2  .AND.  N .NE. 2) CALL TRANS(1)
      IF (IRAD.NE.1) CALL TRANS2
      [illegible]RAD.EQ.2.AND.ITYPE.EQ.1) CALL EFLUX
   20 [illegible])
  203 FO[illegible])
C
```

```
C      **  COMPUTE Y COORDINATE  **
C
       YOND(1) = 0.0
       SUM = 0.0
       DO 40 K=2,NETA
       DETA= ETA(K)-ETA(K-1)
       SUM= SUM +DETA*(1./RHO(K)+1./RHO(K-1))/2.
       YOND(K) = DTIL*SUM
   40  CONTINUE
       DELTA = YOND(NETA)
       DO 50 K=1,NETA
       YOND(K)= YOND(K)/DELTA
   50  CONTINUE
C
C      **  COMPUTE CONVECTIVE HEATING RATE  **
C
C WATTS/CM**3
       QC = -AK(1)*RINF*UINF*UINF2*   (T(2)-T(1))/
      1  (.88*7/8.28          *YOND(2)*DELTA*RZB)
C BTU/FT**2-SEC
       QCP=QC*.88
C
C      **  COMPUTE RADIATIVE FLUX TO SURFACE  **
C
       QR = 0.0
       IF(IRAD .EQ. 1) GO TO 445
       DO 1100 K=2,NETA
       QR = QR + QUAD(YOND,E,K)
 1100  CONTINUE
C WATTS/CM**2
       QR =-QR *RINF*UINF2*UINF *DELTA/(685.*RZB)
       IF(ITYPE.EQ. 0) QR=-QRI(1)
  445  CONTINUE
C BTU/FT**2-SEC
       QRP=QR*0.88
       QTOTAL=QC+QR
```

```
      QTOTP=QTOTAL*.88                                                  OUTP 730
      QCZ=QC                                                            OUTP 740
      QRZ=QR                                                            OUTP 750
      QTZ=QTOTAL                                                        OUTP 760
      QCRAT = 1.0                                                       OUTP 770
      IF(QC.LT.0.0) QCRAT= QC/QCZ                                       OUTP 780
      QRRAT = 1.0                                                       OUTP 790
      IF(QR.LT. 0.0) QRRAT = QR/QRZ                                     OUTP 800
      QTRAT=1.0                                                         OUTP 810
C                                                                       OUTP 820
C **   DIMENSIONALIZE RHO,MU,RM,AK,CP, AND E   **                       OUTP 830
C                                                                       OUTP 840
      DO 450 I = 1 , NETA                                               OUTP 850
      RHO(I)=RHO(I)*RDZ                                                 OUTP 860
      MU (I)=MU(I)*MUDZ                                                 OUTP 870
      RM (I)=RM(I)*RMDZ                                                 OUTP 880
      AK(I) = AK(I)/AKNF                                                OUTP 890
      E(I) = E(I) * RINF     * UINF2 * UINF / (20866.0 * R *RZB)        OUTP 900
      CP(I) = CP(I)/CPNF                                                OUTP 910
  450 CONTINUE                                                          OUTP 920
C                                                                       OUTP 930
C      **  CORRELATION FORMULAS FOR OUTPLT   **                         OUTP 940
C                                                                       OUTP 950
      QKR=16000.0*SQRT(RINF)*(UINF/10000.0)**3.25                       OUTP 960
      QKR=-QKR/SQRT(R)                                                  OUTP 970
      HIS=HTOTAL/(32.174*778.0)                                         OUTP 980
      SRENU=0.763*(PRW      )**0.4 * (RM(NETA)/RM(1)  )**0.4            OUTP 990
      PS=PD*2116.0                                                      OUTP1000
      RS=RHO(NETA)                                                      OUTP1010
      DUEDX=(1.0/R)*SQRT(2.0*PS/RS)                                     OUTP1020
      SDUEDX=SQRT(DUEDX      )                                          OUTP1030
      SRMPR=SQRT(RM(1     ))*32.174/PRW                                 OUTP1040
      QFR=-SRENU*SRMPR*SDUEDX*HIS                                       OUTP1050
      QRT=-495000.0*RINF**1.98*(UINF/10000.0)**14*R                     OUTP1060
      QT=QRT+QKR                                                        OUTP1070
      RLAMDA=QRP/(RINF*UINF**3/(2.*778.28))                             OUTP1080
```

```
C
      GO TO  (1,2,3,4) , N
C
 1    WRITE(6,201) IEM
 201  FORMAT(23H SOLUTION CONVERGED IN  ,I3,11H ITERATIONS //)
      GO TO 4
C
 2    WRITE (6,202) IEM
 202  FORMAT(1H0,37H INTERMEDIATE PRINT AT ITERATION NO. ,I4,//)
      GO TO 4
C
    3 CONTINUE
C
 4    CONTINUE
C
C     **  PRINT SHOCK QUANTITIES AND HEATING RATE  **
C
      XID=0.0
      WRITE(6,204) XID,DELTA,DTIL
  204 FORMAT(1H0,7H XI   = ,F9.4, 9X,9H DELTA = ,1PE14.6,10X,7HDTIL = ,
     1     E15.6)
C
      EPSOT = 0.0
      WRITE (6,210) EPSOT,QC,QCP
  210 FORMAT ( 1H0,7H EPS = ,F9.4,9X,5H QC = E15.6,2X,13H(WATTS/CM**2),
     1       2X,1H=,E15.6,2X,17H(BTU/FT**2 - SEC)          )
      WRITE(6,212) RZB,QR,QRP
  212 FORMAT ( 1H0,6H RB   =,F9.4,10X,5H QR = E15.6,2X,13H(WATTS/CM**2),
     1       2X,1H=,E15.6,2X,17H(BTU/FT**2 - SEC)          )
      WRITE(6,213) RVW,QKR,QFR
  213 FORMAT(1H0,6H RVW= ,F9.4,10X,6H QKR = E14.6,12X,6H QFR = E15.6)
      WRITE (6,214) QRT,QT,RLAMBA
  214 FORMAT (1H ,25X,6H QRT =E14.6,12X,6H QT   = E15.6,8X,
     1      9H   CHR = ,E15.6)
C
      WRITE(6,215) QTOTAL,QTOTP
```

```
215   FORMAT(1H0,16HTOTAL HEATING   = E15.6,2X,13H(WATTS/CM**2),
     1        2X,1H=,E15.6,2X,17H(BTU/FT**2 - SEC)       )
      WRITE(6,216) QCRAT,QRRAT,QTRAT
216   FORMAT(21H0HEATING DISTRIBUTION   ,
     1             5X,9H QC/QCZ = E14.6,2X,8HQR/QRZ = E14.6,2X,
     1                8HQT/QTZ = E14.6  ///)
C
C     **  PRINT Y/D , F AND T PROFILES   **
C
      WRITE(6,205)
205   FORMAT(1H0,7X, 4H ETA, 5X, 4HY/DZ,  8X, 2HF', 8X, 3H RV, 8X ,
     1        4HT/TD,  4X ,13H E(WATTS/CM3),4X,2H V, 7X,12H V (FT/SEC) ,
     2  5X,2H G,6X,12H H (STATIC) , //)
      FP = 0.0
      NS=NSP
      VPOS = 0.
C
      DO 100 I=1,NETA
C COMPUTE ENTHALPIES
      IF(V(I).LT.0.0) VPOS=1.
      IF(VPOS.GT.0.) NS =7
      IF(ITEM.LT.IAB) NS=7
      HSTAT = 0.0
      DO 99 J=1,NS
 99   HSTAT = HSTAT + HS(J,I)*C(J,I)
      G = HSTAT + V(I)**2
C
      HEAD=HEAD2
      IF(I .EQ. 1) HEAD=HEAD1
      IF (I .EQ. NETA) HEAD=HEAD3
      YDZ = YOND(I)
      IF(I.EQ.NETA) FP =1.0
      RV = -FC(I)*DTIL*2.
      VS = V(I) *UINF
      WRITE(6,208) HEAD,ETA(I),YDZ,FP,RV,T(I),E(I),V(I),VS,G,HSTAT
208   FORMAT(1H ,A4,  F6.3,1P10E12.3)
```

```
      IF(I.LT.NETA-1) FP = Z(I)*DTIL
  100 CONTINUE
C
C     **  WRITE OUT SHOCK LAYER GAS PROPERTIES  **
C
      WRITE(6,44)
 44   FORMAT(1H1,48X,28H-SHOCK LAYER GAS PROPERTIES-     )
C
      WRITE(6,206)
 206  FORMAT(1H0,3X,3HETA,8X,4H Y/D,12X,2HP  ,12X,2H T,11X,3HRHO,11X,2HMU
     1        , 12X, 3HRMU,11X,2H K)
C
      WRITE(6,207)
 207  FORMAT (1H ,27X,6H(ATM.),6X,13H (DEG.KEL.)   ,12H(SLUGS/FT3) ,2X,
     1        28H(LBM/FT-SEC) (LBF2-SEC3/FT6) ,16H (BTU/FT-SEC-R) ,//)
C
      DO 101  I=1,NETA
C
      TS = T(I)*TD
      WRITE(6,8)ETA(I),YOND(I),PI(I),TS   ,RHO(I),MU(I),RM (I),AK(I)
C
    8 FORMAT(1H F7.4,1P8E14.4)
    9 FORMAT(1H F7.4,1P7E14.4)
C
  101 CONTINUE
C
C     **  WRITE SPECIES MASS FRACTIONS  **
C
      WRITE(6,230)
  230 FORMAT (1H1,48X,26H-SPECIES MASS FRACTIONS-     )
      WRITE(6,231)
  231 FORMAT (1H ,14X,3H C2,11X,2HN2,11X,3H O ,11X,3H N ,11X,3H O+,
     1        11X,3H N+,11X,3H E-,//)
      DO 102  I=1,NETA
      WRITE(6,8) ETA(I),C(1,I),C(2,I),C(3,I),C(4,I),C(5,I),
     1        C(6,I),C(7,I)
```

```
102   CONTINUE
      WRITE(6,230)
      WRITE(6,233) (SP(I),I=8,15)
233   FORMAT(2X,4H ETA,1X,8(10X,A4)//)
      WRITE(6,8) (ETA(I),      (C(J,I),J= 8,15),I=1,NETA)
      WRITE(6,230)
      WRITE(6,234) (SP(I),I=16,20)
234   FORMAT(2X,4H ETA,7X,3H CP,5(11X,A4),10X,4H AMW//)
      WRITE(6,9) (ETA(I),CP(I),(C(J,I),J=16,20),AMW(I),I=1,NETA)
C NONDIMENSIONALIZE
      DO 1001 I=1,NETA
      RHO(I) = RHO(I)/RDZ
      RM(I) = RM(I)/RMDZ
      E(I)=((E(I)*R)/(RINF*UINF**3))*20866.0*RZB
      CP(I) = CP(I)*CPNF
1001  AK(I) = AK(I)*AKNF
      IF(IEM.LT.3) GO TO 1000
      WRITE(7,217) (T  (I),I=1,NETA)
      WRITE (7,217) (RHO(I),I=1,NETA)
      WRITE (7,217) (RM (I),I=1,NETA)
      WRITE(7,217) (ETA(I),I=1,NETA)
217   FORMAT(6E12.5)
1000  CONTINUE
C
      RETURN
C
      END
```

APPENDIX D

References

D.1 Hansen, C. F., "Approximations for the Thermodynamic Properties of High Temperature Air," NASA TR R-50, 1959.

D.2 Esch, D. D., Stagnation Region Heating of a Phenolic-Nylon Ablator During Return from Planetary Missions, Ph.D. Dissertation, Louisiana State University, Baton Rouge, Louisiana, Aug. 1971.

D.3 Esch, D. D., A. Siripong, R. W. Pike, "Thermodynamic Properties in Polynomial Form for Carbon, Hydrogen, Nitrogen and Oxygen Systems From 300 to 15000°K," NASA RFL TR-70-3, Ch.E. Dept., Louisiana State University, November, 1970.

APPENDIX E

RADCOR COMPUTER PROGRAM

DISCUSSION OF THE PROGRAM

The computer program RADCOR can be used to compute radiative heating rates at the stagnation line or around the body. Heating rate calculations are based on a radiative cooling parameter correlation which is used in conjunction with an isothermal slab radiation calculation made in the program. The isothermal radiation calculation is made for post shock thermodynamic and species levels. Each point on the body is treated independently and thus the heating at the point in question is only dependent on the local shock shape, stand-off distance and free stream conditions.

This program provides the capability of rapidly estimating radiative heating rates at the stagnation line or around the body for no mass injection. Although its primary use is for earth atmospheric entry, heating due to entry into Mars or Venus atmospheres may also be computed. The effects of ablation products may be accounted for by hand calculation methods described in Chapter 5 and 6. Thus the philosophy in using this program is one of obtaining preliminary design estimates of the radiative heating environment about a vehicle.

The basic assumptions of the calculation are:

1. The shock layer can be approximated locally as an infinite plane slab.
2. The body is assumed spherical.
3. The shock wave is assumed concentric.

4. The shock stand-off-distance is computed using

   $$\delta = \bar{\rho}/(\sqrt{8\bar{\rho}/3} + 1)$$

5. Line and continuum radiation of species H, C, O and N are included.

6. Continuum radiation of species CO, O_2, C_2, N_2, C_3 and H_2 are included.

7. Radiation blockage by ablation species is not included.

8. The surface radiative flux can be computed from the isothermal flux using a radiative cooling parameter correlation.

The principle option of the program computes the surface radiative heating for an air atmosphere using the following computation sequents. First, the Rankine-Hogoniot equations (2.79 to 2.82) are solved using the air thermodynamic properties of Hansen (Ref. E.1). Second, the shock stand-off-distance is computed. Third, using the stand-off-distance and post shock species composition from the solution of the Rankine-Hugoniot equations, the isothermal radiative flux is computed. Fourth, the radiative cooling parameter, Γ, and surface radiative heating, q_R, are computed using the following relations from Ref. E.2.

$$\Gamma = \frac{(q_R)_{\text{isothermal}}}{\frac{1}{2}\,\rho_\infty U_\infty^3} \qquad .04 < \Gamma < 1.0 \tag{E.1}$$

$$q_R = (0.2 - 0.295 \log_{10}\Gamma)(q_R)_{\text{isothermal}} \tag{E.2}$$

If the around the body option is used this sequence is repeated at two degree increments around the body.

If the non-air atmosphere option is used the density ratio across the shock and the post shock species, temperature pressure and average

molecular weight must be input and only stagnation line calculations can be made. This option is appropriate for bodies entering either a Mars or Venus atmosphere. The only apparent deficiency for this type of calculation is the possible radiative effect of CN which may exist in significant quantities for some flight conditions.

There are three features of the computer program that make it attractive for preliminary estimates of surface heating rates:

1. The only inputs that are required for air atmosphere problems are the free-stream flight conditions and body radius.

2. A large number of solutions can be obtained in a small amount of computer time (less than .10 min of IBM 360-65 time per case)

3. The program has a modest computer storage required ($\approx$19 K words).

The next section presents the details of the input procedure.

The usefulness of this program would be enhanced if a correlation for the effects of ablation product injection were included in the program. An attempt was made without success to find a suitable correlation as discussed in Chapter 5. If however a suitable correlation is obtained in future work, its addition to this program would improve present accuracy of making rapid preliminary design calculations.

INPUT GUIDE

All inputs to the RADCOR computer program are read from cards. The basic input consist of the free-stream velocity, free stream density or post shock pressure, and the body radius. Four inputs formats are used for input, I5, E12.0, E10.0, and A4. The floating point formats must have the decimal point punched on the card.

Multiple cases for the same kind of problem may be run. The first card input signals the kind of cases to be run. For subsequent cases card 1 is not read and the cases are to be subsequently stacked. Card 1 of the input also serves to indicate multiple runs of a particular kind. Parametric studies may be made by changing the body radius or free-stream velocity holding the other specifying variable constant. This is accomplished by setting NR = no. of body radii or NV = no. of free-stream velocities to a value greater than 1. If this is done, the base case specified by either card 3A or 3B is computed first then the velocity and or body radius is sequentially increased by constant intervals according to the following logic.

$$R = R_{initial} + 2.0\,K \text{ (ft)}$$

where K = 2, ..., NR

$$U_\infty = U_{\infty_{initial}} + 2000.J \text{ (ft/sec)}$$

where J = 2, ..., NV

The U_∞ updating takes place in a loop internal to a loop updating R. Consequently for a given R all NV velocity cases will be run. If the R is updated the velocity is reinitialized and the sequence is repeated.

Table E.1 provides the details of the card input and Tab. E.2 provides a corresponding definition of variables.

TABLE E.1

CARD INPUT FOR RADCOR

Card Type	Variables	Format
1	ITYPE, IBØDY, NR, NV, IATM	8I5
2	TITLE	18A4
3A*	UINF, PDK, R	3E12.0
3B*	UINF, RINF, R	3E12.0
4$	NETA, LINES, IDG, IEZ, XMØL	4I5,E10.0
5#	TD, AMW(NETA, RZB, RE, PD	6E12.0
6#	FRAC(NETA,I)	6E12.0

* The value of ITYPE determines which card is to be read.

ITYPE = 0 Card 3B is read

= 1 Card 3A is read

$ If this card is blank the variable are internally set.

NETA = 5

LINES = 1

IDG = 0

IEZ = 5

XMØL = 1.0

The value of IATM determines whether these two cards are read.

IATM = 0 Neither card is read

= 1 Both cards are read

TABLE E.2

VARIABLE DEFINITIONS FOR RADCOR

Variable	Description
ITYPE	Indicator used for the specification of which option is used for normal shock calculations. ITYPE = 0 Shock conditions computed from free stream velocity and free stream density. = 1 Shock conditions computed from free stream velocity and post shock pressure.
IBØDY	Counter used for the specification of whether solution is found at the stagnation line only or for an around the body concentric shock. IBØDY = 0 or 1 Stagnation line solution only. > 1 Around the body solutions for a concentric shock. Value of IBØDY determines how far around the body the solution is carried.
NR	Counter determining whether R is to be internally updated. NR = 0 R is read for each case. ≥ 1 R is to updated internally. Value of NR determines the number of times R is updated.
NV	Counter determining whether UINF is to updated internally NV = 0 UINF is read for each case. ≥ 1 UINF is to be updated internally. Value of NV determines the number of times UINF is updated.
IATM	Counter determining whether solution is for air atomosphere or any atmosphere. IATM = 0 Solution for air atmosphere only. = 1 Solution for any atmosphere. This solution requires the inputing of the mole fractions for species present in the system.
TITLE	Title for identification of problem.
UINF	Free stream velocity (U_∞ - ft/sec)
POK	Post shock pressure (P_δ - atm.)

RINF	Free stream density (ρ_∞ - slugs/ft^3)
NETA	The number of points used in the slab radiation calculation
LINES	Line radiation option variable LINES = 0 Continuum calculation only. = 1 Coupled line and continuum calculation.
IDG	Switch to allow intermediate printout IDG = 0 Only final results printed. = 1 Print at each ETA is given. = 2 Complete print is given
IEZ	The number of points used in the flux integration. IEZ = 0 The ETA array will be used for the ETZ array. 0<IEZ<NETA Specifies the number of points in the ETZ array.
XMØL	A molecular radiation option switch XMØL = 10^{-6} Molecules not included in the radiation calculated = 1.0 Molecules included in the radiation calculation.
TD	Post shock temperature (T_δ - ^oK)
AMW(NETA)	Average molecular weight of all species present in the system being analyzed.
RZB	Density ratio across the shock ($\frac{\rho_\infty}{\rho_\delta}$) .
RE	Reynold's number = $Re_\delta = \rho_\infty U_\infty R/\mu_{\delta,0}$
PD	Post shock pressure (P_δ)
FRAC(NETA,I)	Post shock mole fractions of species I used in input of non-air atmospheres. I = 1 = O_2 4 = O 7 = H 10 = CO 2 = N_2 5 = E^- 8 = C_2 11 = C_3 3 = O 6 = C 9 = H_2

OUTPUT DESCRIPTION

This section presents a description of the output format and definition of output symbols. The reader may find it instructive to refer to the listing of the sample problem given in the next section.

The first page of output consists of a print of the title card and the options specified on card 4. This provies an identification of the problem and a check on some of the pertinent options.

The second page of standard output (i.e. IDG = 0) is a print of the results for one case. Under the heating of "SHOCK LAYER GAS PROPERTIES" the free-stream and post shock conditions are given. Names and meanings not listed in the foregoing section are:

HTØTAL = Free-stream total enthalpy

VD = Post shock normal velocity

(R*U)INF = Free-stream mass flux per unit area

Under the heading of "SPECIES MASS FRACTIONS" the post shock species mass fractions of air are listed if the air atmosphere option is used. No listing is given for other atmospheres. Under the heading of "RADIATIVE FLUX PROPERTIES" information pertaining to the radiative heating calculation is given. The names and descriptions of the variables printed are:

PATHLENGTH = Path length used in the isothermal radiation calculation which equals the stand-off distance.

GAMMA = Γ of Eq. (E.1)

ISOTHERMAL FLUX = $(q_R)_{ISOTHERMAL}$ of Eq. (E.1).

ACTUAL FLUX = q_R (surface heating rate)

CHR = Radiative heat transfer coefficient

DELTA/R = δ (nondimensional stand-off distance)

.5RINF*UINF3 = $.5\ \rho_\infty U_\infty^{\ 3}$ (free stream kinetic energy flux per unit area)

QRR = $(q_R)/(q_R)_0$ the heating rate referenced to the stagnation value

If the parameter IDG is greater than 0 additional output from the radiation calculation is given. This output is similar to that discussed in Appendix C and thus will not be detailed here.

SAMPLE PROBLEM AND PROGRAM LISTING

The following example is presented to illustrate the basic input for the RADCØR program and to show a typical output listing. The conditions defining the problem are

U_∞ = 50000 ft/sec

$\rho_\infty = 9.0 \times 10^{-7}$ slug/ft^3

R = 9 ft

The heating rate results shown are for the stagnation point in an air atmosphere. The following is a typed listing of the necessary input cards for this problem (the zeros need not be punched).

```
0       0       0       0       0
SAMPLE CASE
50000.          9.0E7   9.0
0       0       0       0       0.0
```

The four cards required for this sample case are cards 1, 2, 3B and 4.

A computer output listing for this problem is given on the following pages. This output listing is followed by a Fortran listing of the computer program.

SAMPLE CASE

5 1 0 5 0.100E 01

-SHOCK LAYER GAS PROPERTIES-

UINF (FT/SEC)	RINF (SLUG/FT**3)	HTOTAL (FT**2/SEC**2)	TD (OK)	PD (ATM)
5.0000E 04	9.0000E-07	1.2500E 09	1.5032E 04	9.9953E-01

RZB	PE	VD (FT/SEC)	(R*U)INF LB/FT**2-SEC	R (FT)
5.0000E-02	2.2045E 06	-3.0000E 03	1.4478E 00	9.0000E 00

-SPECIES MASS FRACTIONS-

O2	N2	O	N
3.9552E-07	6.3390E-05	1.0550E-01	3.6920E-01

O+	N+	E-
1.1569E-01	4.0490E-01	1.9864E-05

-RADIATIVE FLUX PROPERTIES-

PATHLENGTH (CM)	GAMMA	ISOTHERMAL FLUX (WATTS/CM**2)	ACTUAL FLUX (WATTS/CM**2)	CHR	DELTA/R	.5RINF*UINF3 (WATTS/CM**2)
0.1176E 02	0.6704E 00	0.2753E 05	0.6915E 04	0.8421E-01	0.4286E-01	0.8213E 05

QRR
0.1000E 01

```
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C  THIS PROGRAM COMPUTES RADIATIVE HEATING RATES USING A RADIATIVE
C  LOSS PARAMETER CORRELATION                   C ENGEL  6-1-71
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /NON/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/PROP1/PI( 5),RHO( 5),TI( 5),AMW( 5),C(20,5)
      COMMON/PROP2/  MU( 5)
      COMMON/PROP4/PL,ROR,EI,FISO,QR,RLANDA,DELTAR     ,RU3,GAMMA
      COMMON /VEL/ F( 5),FC( 5),Z( 5),V( 5)
      COMMON /RH/ DUD,DPHI,TD,RZB,PC,HC,HTOTAL ,VD
      COMMON /OPT/ ITYPE , PDK ,IPAGE,THETA,PHI,EPS
      COMMON /SPEC/     XMCL
      COMMON /IRN/ YD( 5),NUT( 5), FMC(12, 5), FPC(12, 5),
     1             FM(9, 5), FP(9, 5), LINES
      COMMON /MAIN1/ NXI,  MAXG,  MAXM,  MAXS,  IDG,     MCONV,
     1  GCONV, SCONV
      COMMON /SFLUX/ QRI(3),QRR
      COMMON /MOLFRA/    X1( 5),X2( 5),   X3( 5),   X4( 5),
     1                           X7( 5),  X8( 5),  X9( 5),  X10( 5),
     2                  X11( 5),  X12( 5),  X13( 5)
      COMMON /NUMDEN/ SNCC2( 5), SNDN2( 5), SNDO( 5), SNDN( 5),
     1                                      SNDE( 5), SNDC( 5),
     2                SNCH( 5), SNDC2( 5), SNDH2( 5), SNDCO( 5),
     3                SNCC3( 5)
      DIMENSION DENS( 5,11), TIT(20),FRAC ( 5,11)
      EQUIVALENCE (SNDO2(1),DENS(1,1))
      EQUIVALENCE (X1(1),FRAC(1,1))
      DIMENSION TITLE(18)
      REAL  MU,MUDZ
      IPAGE=1
CCARD 1-----------------------------------------------------------------
      READ(5,116)ITYPE,IBCDY,NR,NV,IATM
CCARD 2-----------------------------------------------------------------
   10 READ (5,100) TITLE
      WRITE(6,115)
```

```
C                                                                       MAIN 370
C   **  ZERO ALL NUMBER DENSITIES AND MOLE FRACTIONS  **                MAIN 380
C                                                                       MAIN 390
      DO 20 I=1, 5                                                      MAIN 400
      DO 20 J=1,11                                                      MAIN 410
      FRAC(I,J)=0.0                                                     MAIN 420
   20 DENS(I,J)=0.0                                                     MAIN 430
CCARD 3A----------------------------------------------------------------MAIN 440
      IF(ITYPE.EQ.1)READ(5,118)UINF,PDK,R                               MAIN 450
      WRITE ( 6,101 ) TITLE                                             MAIN 460
CCARD 3B----------------------------------------------------------------MAIN 470
      IF(ITYPE.EQ.0)READ(5,118)U INF,R INF, R                           MAIN 480
CCARD 4-----------------------------------------------------------------MAIN 490
      READ(5,201)NETA,      LINES,ICG,IEZ,XMOL                          MAIN 500
      IF(NETA.EQ.0)NETA=5                                               MAIN 510
      IF(LINES.EQ.0)LINES=1                                             MAIN 520
      IF(IDG.EQ.0)IDG=0                                                 MAIN 530
      IF(IEZ.EQ.0)IEZ=5                                                 MAIN 540
      IF(XMOL.EQ.0.0) XMOL= 1.0                                         MAIN 550
      IF(IATM.EQ.0)GO TO 30                                             MAIN 560
CCARD 5-----------------------------------------------------------------MAIN 570
      READ(5,102)TD,AMW(NETA),RZB,RE,PD                                 MAIN 580
CCARD 6-----------------------------------------------------------------MAIN 590
      READ(5,102)(FRAC(NETA,I),I=1,11)                                  MAIN 600
      RHC(NETA) = 1.0                                                   MAIN 610
      RDZ = RINF/RZB                                                    MAIN 620
      RE=0.0                                                            MAIN 630
      VD=-RZB*UINF                                                      MAIN 640
      HTOTAL=UINF**2/2.0                                                MAIN 650
   30 CONTINUE                                                          MAIN 660
C       ITYPE= 0 RINF=GIVEN                                             MAIN 670
C              1 PD=GIVEN                                               MAIN 680
C       IBODY= 0 OR 1 STAGNATION LINE                                   MAIN 690
C             GT 1 AROUND THE BODY, CONCENTRIC SHOCK                    MAIN 700
C       NR    = 0 OR 1 R READ EACH CASE                                 MAIN 710
C             GT 1 R UPDATED INTERNALLY                                 MAIN 720
```

```
C
C     NV    = 0 OR 1 UINF READ EACH CASE
C           GT 1 UINF UPDATED INTERNALLY
C
C  ** NETA = NUMBER OF ETA POINTS
C     LINES= 1   IF LINE CALCULATION IS TO BE DONE
C            0   IF ONLY CONTINUUM CALCULATION IS TO BE DONE
C     IDG   = 0   ONLY FINAL PRINT IS GIVEN
C             1   PRINT IS GIVEN FOR EACH ETA
C            99   COMPLETE PRINT
C     IEZ   = 0   IF ETA ARRAY WILL ALSO BE USED FOR ETZ.
C             OTHERWISE IEZ= NUMBER OF POINTS IN  ARRAY ETZ TO BE
C             INPUT. WILL BE LESS THAN NETA
C     IATM =0 AIR SPECIES
C     IATM =1  ARBITRARY SPECIES SHOCK PROPRERTIES READ IN
C
      WRITE (6,202) NETA      ,LINES,IDG,IEZ,XMOL
C
C
C  ** R        = BODY RADIUS (FT)
C     DELTA    = NONDIMENSIONAL STAND-OFF DISTANCE
C     XMOL     = 1.0 FOR RUN WITH MOLECULES
C                0.0 FOR RUN WITHOUT MOLECULES
C
      IF(NR.EQ.0)NR=1
      DO70K=1,NR
      IF(NV.EQ.0)NV=1
C
      DO 60J=1,NV
      I = NETA
C
C  **  AROUND THE BODY CALCULATIONS FOR A CONCENTRIC SHOCK   **
C
      THETA=0.0
      IF(IBODY.EQ.0)IBODY=1
      DO 40KK=1,IBODY
      PHI=THETA
```

```
      EPS=THETA-PHI
C
      IF(IATM.EQ.0)CALL SHOCK
C
      CALL FLUX
C
      RUINF=RINF*UINF*32.174
      WRITE(6,119)
      WRITE(6,123)IPAGE
      WRITE(6,103)
      WRITE(6,104)
      WRITE(6,105)
      WRITE(6,106)UINF,RINF,HTOTAL,TC,PD
      WRITE(6,110)
      WRITE(6,111)
      WRITE(6,112)RZB,RE,VC,RUINF,R
      IF(IATM.GT.0)GO TO 35
      WRITE(6,107)
      WRITE(6,108)
      WRITE(6,109)C(1,I),C(2,I),C(3,I),C(4,I)
      WRITE(6,113)
      WRITE(6,114)C(5,I),C(6,I),C(7,I)
   35 CONTINUE
      WRITE(6,126)
      WRITE(6,120)
      WRITE(6,121)
                        PL,GAMMA,FISO,CR,RLANDA,DELTAR,RU3
      WRITE(6,122)
      WRITE(6,125)
      WRITE(6,124)QRR
      IPAGE=IPAGE+1
      THETA = THETA +2.0*3.1415/180.
   40 CONTINUE
      IF(NV.GT.1) UINF=UINF +2000.
   60 CONTINUE
      IF(NR.GT.1)R=R+2.0
   70 CONTINUE
```

```
      GO TO 10
C
C     **  FORMATS FOR READ STATEMENTS  **
C
  116 FORMAT(8I5)
 100  FORMAT (18A4)
  118 FORMAT(4E12.0)
  102 FORMAT (6E12.0)
  201 FORMAT (4I5.E10.0)
C
C     **  FORMATS FOR WRITE STATEMENTS  **
C
  101 FORMAT(     1H0, 18A4 / )
  115 FORMAT(1H1)
  119 FORMAT(1H1)
  123 FORMAT(74X,'PAGE NO.',I5)
  103 FORMAT(1H ,18X,28H-SHOCK LAYER GAS PROPERTIES-)
  104 FORMAT(1H0,5X,5H UINF ,10X,5H RINF ,7X,7H HTOTAL , 9X,3H TD ,
     111X,3H PD )
  105 FORMAT(1H ,3X,9H (FT/SEC) ,4X,13H (SLUG/FT**3) ,
     115H (FT**2/SEC**2) ,3X,5H (OK), 8X,6H (ATM) )
  106 FORMAT(1P5E14.4,//)
  110 FORMAT(1H0,6X,4H RZB ,11X,3H RE ,10X,3H VD ,7X,9H (R*U)INF,8X,
     1    'R')
  111 FORMAT(1H ,31X,9H (FT/SEC) ,4X,13H LB/FT**2-SEC,3X,'(FT)').
  112 FORMAT(1P5E14.4,//)
  107 FORMAT(1H ,18X,26H -SPECIES MASS FRACTIONS-    )
  108 FORMAT(1H ,14X,3H C2,11X,2HN2,11X,3H O ,11X,3H N    )
  109 FORMAT(7X,1P4E14.4,//)
  113 FORMAT(1H ,14X,3H C+ ,11X,3H N+ ,11X,3H E-)
  126 FORMAT(18X,'-RADIATIVE FLUX PROPERTIES-',/)
  114 FORMAT(7X,1P3E14.4,//)
  120 FORMAT(2X,'PATHLENGTH',7X,'GAMMA',2X,'ISOTHERMAL FLUX',2X,
     1    'ACTUAL FLUX',6X,' CHR ',8X,'DELTA/R',4X,'.5RINF*UINF3')
  121 FORMAT(5X,'(CM)', 20X,                  '(WATTS/CM**2)',1X,
     1    '(WATTS/CM**2)',27X,'(WATTS/CM**2)')
```

```
 122 FORMAT(1X,7(E11.4,3X))                                         MAIN1810
 125 FORMAT(/,7X,'ORR',//)                                          MAIN1820
 124 FORMAT(1X,E14.4)                                               MAIN1830
202  FORMAT (4I5,E12.3)                                             MAIN1840
     STOP                                                           MAIN1850
     END                                                            MAIN1860
```

```
      SUBROUTINE SHOCK
C
C     ** THIS SUBROUTINE COMPUTES THE STRONG SHOCK JUMP CONDITIONS
C      FOR A SPECIFIED SHOCK ANGLE USING AIR GAS PROPERTIES  **
C
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /NCN/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/PRCP1/PI( 5),RHO( 5),T ( 5),AMW( 5),C(20,5)
      COMMON/PROP2/  MU( 5)
      COMMON /VEL/ F( 5),FC( 5),Z( 5),V( 5)
      COMMON /RH/ CLO,DPHI,TD,RZB,PD,HD,HTOTAL ,VD
      COMMON/PRCP4/PL,RCR,EI,FISO,GR,RLANDA,DELTAR     ,RU3,GAMMA
      COMMON /OPT/ ITYPE , PDK ,IPAGE,THETA,PHI,EPS
      REAL  MU,MUDZ
C
C     **  DETERMINE DENSITY RATIO , REYNCLDS NUMBER
C          FROM INPUTS OR RANKINE HUGONIOT EOS.   **
C
C     GUESS RINF
C
      IF(ITYPE.EQ.1) RINF= 10.0**(ALOG10(PDK)-6.)
      UINF2=UINF**2
      NETA=5
      HTOTAL=UINF2/2.0
C
C GUESSED VALUES
C
   20 TD = 12000. + .5E-5*(HTOTAL -6.5E+8)
      RZB=.06
C
      T(NETA) = 1.0
  998 CONTINUE
C     ** CONVERGENCE LOOP FOR RZB  **
C
      PD=(1.-RZB)*COS(PHI)*COS(PHI)*RINF*UINF2/2116.
      HD=(1.-RZB**2)*COS(PHI)*COS(PHI)*UINF2/(2.*778.28*32.174)
```

```
      PI(NETA) = PD                                              SHOC 370
      CALL GAS(NETA)                                             SHOC 380
      RZB1=RINF/(RDZ*RHO(NETA) )                                 SHOC 390
      TEST =ABS((RZB-RZB1)/RZB)                                  SHOC 400
      IF(TEST .LT. 0.005) GO TO 999                              SHOC 410
      RZB=.5*(RZB+RZB1)                                          SHOC 420
      GO TO 998                                                  SHOC 430
  999 CONTINUE                                                   SHOC 440
C     **  RANKIN-HUGONIOT RELATIONS  **                           SHOC 450
C                                                                SHOC 460
      PD=(1.-RZB)*COS(PHI)*COS(PHI)*RINF*UINF2/2116.             SHOC 470
      RE = RDZ*UINF*R*32.174 / MUDZ                              SHOC 480
      VD=(SIN(PHI)*SIN(EPS)-RZB*COS(PHI)*COS(EPS))*UINF          SHOC 490
C     **  CONVERGENCE LOOP FOR PRESSURE  **                      SHOC 500
C                                                                SHOC 510
      IF(ITYPE.EQ.0) GO TO 50                                    SHOC 520
      TEST1=(PDK-PD)/PDK                                         SHOC 530
      IF(ABS(TEST1).LE..001) GO TO 50                            SHOC 540
      RINF=(1.+.6*TEST1)*RINF                                    SHOC 550
      GO TO 20                                                   SHOC 560
   50 CONTINUE                                                   SHOC 570
      RETURN                                                     SHOC 580
      END                                                        SHOC 590
```

```
      SUBROUTINE FLUX
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON/RH/ DUC,DPHI, ID, RZB,PD,HC,HTCTAL,VD
      COMMCN/PRCP4/PL,RCR,EI,FISO,QR,RLANDA,DELTAR    ,RU3,GAMMA
      COMMON /SFLUX/ QRI(3),CRR
      COMMON /OPT/ ITYPE , PDK ,IPAGE,THETA,PHI,EPS
C    **  DETERMINE RADIATIVE FLUX  **
C
      DELTAR=RZB/(1.+SQRT(8./3.*RZB))
C     **  STANDOFF DISTANCE IN CM.  **
C
      DELTA=DELTAR*R*30.48
C     **  CALCULATION OF PATH LENGTH  **
C
      PL=  DELTA
C     **  CALCULATION OF   ISOTHERMAL FLUX,AND FLUX LOSS  **
C
      CALL LRAD
C
      FISO=QRI(1)
      RU3 = .5*RINF*(UINF**3)/(778.28*.88)
      GAMMA=2.*FISO/RU3
C
C      **  CALCULATION OF ACTUAL FLUX  **
C
      CR=(.2-.295*ALOG10(GAMMA))*FISO
      IF(THETA.EQ.0.0)QRC=QR
      CRR=QR/QRC
C    **  RADIATIVE HEAT TRANSFER COEFFICIENT  **
C
      RLANDA=CR*778.28*2./(RINF*UINF**3/.88)
      RETURN
      END
```

```
      SUBROUTINE GAS (KODE )
C
C     **   THERMODYNAMIC AND TRANSPORT PROPERTIES OF AIR **
C     **  REFERENCE NASA TR R-50 **
C
C THE FOLLOWING PROPERTIES ARE CALCULATED
C                TEMPERATURE AT WHICH PROPERTIES ARE WANTED (T) IN DEG R
C                PRESSURE AT WHICH PROPERTIES ARE WANTED (P) IN LB/IN**2
C                RATIO OF SPECIFIC HEATS (GAMMA) IN DIMENSIONLESS
C                SPECIFIC HEAT AT CONSTANT PRESSURE (CP) IN BTU/LB-DEG R
C                ABSOLUTE VISCOSITY (V) IN LB/FT-SEC
C                PRANDTL NUMBER (PR) IN DIMENSIONLESS
C                THERMAL CONDUCTIVITY (XK) IN BTU/FT-SEC-DEG R
C                PRESSURE (P) IN ATMOSPHERES
C                DENSITY (DEN) IN LB/FT**3
C                 ENTHALPY (H) IN BTU/LB
C                 ENTROPY (S) IN BTU/LB-DEG R
C                 COMPRESSIBILITY (Z) IN DIMENSIONLESS
C                 SPECIFIC HEAT AT CONSTANT VOLUMN (CV)  IN BTU/LB-DEG R
C                 SPEED OF SOUND (SOS) IN FT/SEC
C                 ENTROPY (S) IN FT**2/SEC**2
C                 VELOCITY (VEL) IN FT/SEC
C                 PRESSURE (P) IN LBS/FT**2
C                 MACH NUMBER (M) IN DIMENSIONLESS
C
C
C NOMENCLATURE    1=OXYGEN MOLECULES, 2=NITROGEN MOLECULES, 3=OXYGEN ATMOS
C                 4=NITROGEN ATMOS, 5=OXYGEN IONS, 6=NITROGEN IONS
C                 7=ELECTRONS
C
C
C
      COMMON /FRSTRM/ U INF, RINF, UINF2, R , RE, LXI, ITM, IEM, NETA
      COMMON /NON/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON/PROP1/PI( 5),RHO( 5),TI( 5),AMW( 5),C(20,5)
      COMMON/PROP2/  MU( 5)
      COMMON /RH/ DLD,DPHI,TC,RZB,PD,HD,HTOTAL ,VD
```

```
      COMMCN/WALL/RVW,PRW,TWOLD,FLUX(20),CWALL(20),ECWALL(5)
      COMMON/MOLFRA/ XN1(5),XN2(5),XN3(5),            XN4(5),XN7(5),
     1     XN8(5),XN9(5),XN1C(5),XN11(5),XN12(5),XN13(5)
      REAL  MU,MUCZ
      LOGICAL MCCNV,GCONV,SCONV
      DATA GASC /49721.7/
C
C
      DO 2COC I=KODE,NETA
      T = TI(I) * TD
      P = PI(I)
C
C THE FOLLOWING PART CF PROGRAM USES PRESSURE IN ATMOSPHERES
C AND TEMPERATURE IN DEG K
C
      ITER=C
C
C     **  TEMPERATURE - ENTHALPY ITERATION  **
C
  900 CONTINUE
      ITER=ITER+1
      IF(T.LT.10C.) T=10C.
      A1=1139C./T
      A2=18990./T
      A3=227C./T
      A4=339C./T
      A5=228./T
      A6=326./T
      A7=228CC./T
      A8=486CC./T
      A9=277CC./T
      A1C=41500./T
      A11=386C0./T
      A12=582C0./T
      A13=70.6/T
      A14=188.9/T
```

```
      A15=22CC0./T                                                      GAS  730
      A16=47CC0./T                                                      GAS  740
      A17=679C0./T                                                      GAS  750
      A18=227C./(4.*T)                                                  GAS  760
      A19=TANH(A18)                                                     GAS  770
      A20=3390./(4.*T)                                                  GAS  780
      A21=TANH(A20)                                                     GAS  790
      TT=1./T                                                           GAS  800
      TSQ=T**2                                                          GAS  810
      TSQRT=T**.5                                                       GAS  820
      A22=112.2222/T                                                    GAS  830
      A23=T/590CC.                                                      GAS  84C
      A24=T/1132CC.                                                     GAS  850
      A25=T/754CC.                                                      GAS  860
      AA1=EXP(-A1)                                                      GAS  870
      AA2=EXP(-A2)                                                      GAS  88C
      AA3=EXP(A3)                                                       GAS  890
      AA4=EXP(A4)                                                       GAS  900
      AA5=EXP(-A5)                                                      GAS  910
      AA6=EXP(-A6)                                                      GAS  920
      AA7=EXP(-A7)                                                      GAS  930
      AA8=EXP(-A8)                                                      GAS  940
      AA9=EXP(-A9)                                                      GAS  95C
      AA1C=EXP(-A10)                                                    GAS  960
      AA11=EXP(-A11)                                                    GAS  970
      AA12=EXP(-A12)                                                    GAS  980
      AA13=EXP(-A13)                                                    GAS  99C
      AA14=EXP(-A14)                                                    GAS 1CCC
      AA15=EXP(-A15)                                                    GAS 1C10
      AA17=EXP(-A17)                                                    GAS 1020
      AA16=EXP(-A16)                                                    GAS 1030
C     CALCULATING ENERGIES PER COMPONENT CF GAS MIXTURE ABOVE           GAS 104C
C     REFERENCE ENERGIES.                                               GAS 1C5C
      E1=2.5+((2.*AA1*A1+AA2*A2)/(3.+2.*AA1+AA2))+(A3/(AA3-1.))         GAS 1060
      ET=2.5+ (A4/(AA4-1.))                                             GAS 1070
      E3=1.5+((3.*AA5*A5+AA6*A6+5.*AA7*A7+AA8*A8)/(5.+3.*AA5+AA6+5.*AA7+GAS 1080
```

```
     1AA8))                                                              GAS 1090
      E4=1.5+((1C.* AA9*A9+6.*AA1C*A10)/(4.+10.*AA9+6.*AA10))            GAS 1100
      E5=1.5+((1C.*AA11*A11+6.*AA12*A12)/(4.+10.*AA11+6.*AA12))          GAS 1110
      E6=1.5+((3.*AA13*A13+5.*AA14*A14+5.*AA15*A15+AA16*A16+5.*AA17*A17)GAS 1120
     1/(1.+3.*AA13+5.*AA14+5.*AA15+AA16+5.*AA17))                        GAS 1130
      E7=1.5                                                             GAS 1140
C TOTAL ENERGY PER COMPONENT OF GAS MIXTURE                               GAS 1150
      EN1=E1                                                             GAS 1160
      EN2=ET                                                             GAS 1170
      EN3=E3+295CC./T                                                    GAS 1180
      EN4=E4+566CC./T                                                    GAS 1190
      EN5=E5+1875C0./T                                                   GAS 1200
      EN6=E6+22540C0./T                                                  GAS 1210
      EN7=E7                                                             GAS 1220
C LOGS OF PARTITION FUNCTICNS                                            GAS 1230
      IL1=ALCG(T)*3.5                                                    GAS 1240
      TL2=ALCG(T)*2.5                                                    GAS 1250
      EQ1=TL1+.11+ALOG((3.+2.*AA1+AA2)/(1.-(1.0/AA3)))                   GAS 1260
      EQ3=TL2+.5+ALCG((5.+3.*AA5+AA6+5.*AA7+AA8))                        GAS 1270
      EQ2=TL1-.42-ALOG((1.-(1.0/AA4)))                                   GAS 1280
      EQ4=TL2+.3+ALCG((4.+10.*AA9+6.*AA10))                              GAS 1290
      EQ5=TL2+.5+ALCG((4.+10.*AA11+6.*AA12))                             GAS 1300
      EQ6=TL2+.3+ALOG((1.+3.*AA13+5.*AA14+5.*AA15+AA16+5.*AA17))         GAS 1310
      EQ7=TL2-14.24                                                      GAS 1320
C EQUILIBRIUM CCNSTANS FCR CHEMICAL REACTIONS                             GAS 1330
      EK1=-5900C./T+2.*EC3-EC1                                           GAS 1340
      EK2=-11320C./T+2.*EC4-EQ2                                          GAS 1350
      EK3=-1580CC./T+EQ5+EC7-EQ3                                         GAS 1360
      EK4=-1688CC./T+EQ6+EQ7-EQ4                                         GAS 1370
      CCC=-79.9                                                          GAS 1380
      IF(EK1.LE.CCC) EK1=-79.9                                           GAS 1390
      IF(EK2.LE.CCC) EK2=-79.9                                           GAS 1400
      IF(EK3.LE.CCC) EK3=-79.9                                           GAS 1410
      IF(EK4.LE.CCC) EK4=-79.9                                           GAS 1420
      XK1=EXP(EK1)                                                       GAS 1430
      XK2=EXP(LK2)                                                       GAS 1440
```

```
      XK3=EXP(EK3)                                                      GAS 1450
      XK4=EXP(EK4)                                                      GAS 1460
      XK34=.2*XK3+.8*XK4                                                GAS 1470
      EE1=(-0.8+(.64+.8*(1.+((4.*P)/XK1)))**0.5)/(2.*(1.+4.*P/XK1))     GAS 1480
      EE2=(-0.4+(.16+3.84*(1.+(4.*P)/(XK2)))**0.5)/(2.*(1.+4.*P/XK2))   GAS 1490
      EE3= 1./(( 1.+P/XK34)**.5)                                        GAS 1500
C COMPRESSIBILITY (Z) DIMENSIONLESS                                     GAS 1510
      Z=1.+EE1+EE2+2.*EE3                                               GAS 1520
C COMPONENT MOL FRACTIONS IN AIR                                        GAS 1530
      X1=(.2-EE1)/Z                                                     GAS 1540
      X2=(.8-EE2)/Z                                                     GAS 1550
      X3=(2.*EE1-.4*EE3)/Z                                              GAS 1560
      X4=(2.*EE2-1.6*EE3)/Z                                             GAS 1570
      X5= .4*EE3/Z                                                      GAS 1580
      X6= 1.6*EE3/Z                                                     GAS 1590
      X7= 2.*EE3/Z                                                      GAS 1600
      IF(X1.LE.0.)  X1=1.E-20                                           GAS 1610
      IF(X2.LE.0.)  X2=1.E-20                                           GAS 1620
      IF(X3.LE.0.)  X3=1.E-20                                           GAS 1630
      IF(X4.LE.0.)  X4=1.E-20                                           GAS 1640
      IF(X5.LE.0.)  X5=1.E-20                                           GAS 1650
      IF(X6.LE.0.)  X6=1.E-20                                           GAS 1660
      IF(X7.LE.0.)  X7=1.E-20                                           GAS 1670
C ENERGY PER MOL OF INITIALLY UNDISSOCIATED AIR-DIMENSIONLESS           GAS 1680
      ER= Z*(X1*EN1+X2*EN2+X3*EN3+X4*EN4+X5*EN5+X6*EN6+X7*EN7)          GAS 1690
C ENTHALPY PER INITIAL MOL OF AIR-DIMENSIONLESS                         GAS 1700
      HR=ER+Z                                                           GAS 1710
C ENTHALPY PER INITIAL MOL OF AIR (H) IN BTU/LB                         GAS 1720
      H=HR*T*.12348                                                     GAS 1730
      IF(KODE.LT.NETA) GO TO 1000                                       GAS 1740
      HRATO=.5*(H-HD)/H                                                 GAS 1750
      AHR   = ABS( HRATO )                                              GAS 1760
      IF(AHR .LE. 0.0010) GO TO 999                                     GAS 1770
      IF(ITER .GT.1) GO TO 203                                          GAS 1780
      TP=T                                                              GAS 1790
      HP=HRATO                                                          GAS 1800
```

```
      T = T *(1. - HRATO )
      IF(ITER .LT. 15) GO TO 900
 203  CONTINUE
      TS=T*(1.0-HRATO)
      IF(HRATO*HP .LT.0.0) TS=.5*(T+TP)
      TP=T
      T=TS
      HP=HRATO
      IF(ITER .LT. 15) GO TO 900
      WRITE(6,200) T,H,HT
 200  FORMAT(39H1TEMPERATURE-ENTHALPY DID NOT CONVERGE /3E15.6)
C     CALL OUTPUT(4)
      STOP
 999  CONTINUE
      TD = T
C
 1000 CONTINUE
C ENTROPY PER INITIAL MOL OF AIR-DIMENSIONLESS
      D1=EQ1+E1+1.
      D2=EQ2+ET+1.
      D3=EQ3+E3+1.
      D4=EQ4+E4+1.
      D5=EQ5+E5+1.
      D6=EQ6+E6+1.
      D7=EQ7+E7+1.
C TOTAL ENTROPY
      SR=Z*(X1*D1+X2*D2+X3*D3+X4*D4+X5*D5+X6*D6+X7*D7)-Z*(X1*ALOG(X1) +
     1X2*ALOG(X2)+X3*ALOG(X3)+X4*ALOG(X4)+X5*ALOG(X5)+X6*ALOG(X6)+X7*
     2ALOG(X7))-Z*ALOG(P)
C ENTROPY PER INITIAL MOL OF AIR (S) IN BTU/LB-DEG R
      S    =SR*0.0686
C SPECIFIC HEAT AT CONSTANT VOLUME-CV
      FF1=3.+2.*AA1+AA2
      CV1=2.5+((2.*AA1*A1*A1+AA2*A2*A2)/FF1)-(((2.*AA1*A1+AA2*A2)/FF1)**
     12.)+((.25*A3*A3)/(((2.*A19)/(1.-A19*A19))**2))
      CV2=2.5+((.25*A4*A4)/(((2.*A21)/(1.-A21*A21))**2))
```

```
      CV3=1.5+((3.*AA5*A5*A5+AA6*A6*A6+5.*AA7*A7*A7+AA8*A8*A8)/(5.+3.*AAGAS 2170
     1S+AA6+5.*AA7+AA8))-((E3-1.5)**2.)                                 GAS 2180
      CV4=1.5+((10.*AA9*A9*A9+6.*AA10*A10*A10)/(4.+10.*AA9+6.*AA10))    GAS 2190
     1-((E4-1.5)**2.)                                                   GAS 2200
      CV5=1.5+((10.*AA11*A11*A11+6.*AA12*A12*A12)/(4.+10.*AA11+6.*AA12))GAS 2210
     1-((E5-1.5)**2.)                                                   GAS 2220
      CV6=1.5+((3.*AA13*A13*A13+5.*AA14*A14*A14+5.*AA15*A15*A15+AA16*A16GAS 2230
     1*A16+5.*AA17*A17**2)/(1.+3.*AA13+5.*AA14+5.*AA15+AA16+5.*AA17))-((GAS 2240
     2E6-1.5)**2.)                                                      GAS 2250
      CV7=1.5                                                           GAS 2260
C LOGARITHMIC DERIVATIVES                                               GAS 2270
      CK1=TT*(59000./T+2.*E3-E1)                                        GAS 2280
      CK2=TT*(113200./T+2.*E4-ET)                                       GAS 2290
      CK3=TT*(158000./T+E5+E7-E3)                                       GAS 2300
      CK4=TT*(168800./T+E6+E7-E4)                                       GAS 2310
      CK34=.2*CK3+.8*CK4                                                GAS 2320
      PK1= CK1+TT                                                       GAS 2330
      PK2= CK2+TT                                                       GAS 2340
      PK3= CK3+TT                                                       GAS 2350
      PK4= CK4+TT                                                       GAS 2360
      PK34=0.2*PK3+0.8*PK4                                              GAS 2370
C PARTIAL DERIVATIVES REQUIRED FOR CP                                   GAS 2380
      DE1P=(PK1*EE1*(1.+EE1)*(.2-EE1))/(.8*(.5-EE1))                    GAS 2390
      DE2P=(PK2*EE2*(1.2+EE2)*(.8-EE2))/(.4*(4.8-EE2))                  GAS 2400
      DE3P=.5*PK34*EE3*(1.-EE3**2)                                      GAS 2410
      DZX1P=-DE1P                                                       GAS 2420
      DZX2P=-DE2P                                                       GAS 2430
      DZX3P=2.*DE1P - .4*DE3P                                           GAS 2440
      DZX4P=2.*DE2P-1.6*DE3P                                            GAS 2450
      DZX5P=.4*DE3P                                                     GAS 2460
      DZX6P=1.6*DE3P                                                    GAS 2470
      DZX7P=2.* DE3P                                                    GAS 2480
C EQUATION FOR SPECIFIC HEAT AT CONSTANT PRESSURE                       GAS 2490
      CPR=Z*(X1*(CV1+1.)+X2*(CV2+1.)+X3*(CV3+1.)+X4*(CV4+1.)+X5*(CV5+1. GAS 2500
     1)+                                                                GAS 2510
     2X6*(CV6+1.)+X7*(CV7+1.))+T*(DZX1P*(EN1+1.)+DZX2P*(EN2+1.)+DZX3P*(EGAS 2520
```

```
     3N3+1.)+DZX4P*(EN4+1.)+DZX5P*(EN5+1.)+DZX6P*(EN6+1.)+DZX7P*(EN7+1.)GAS 2530
     4)                                                                 GAS 2540
C SPECIFIC HEAT AT CONSTANT  PRESSURE (CP) IN BTU/LB-DEG R              GAS 2550
      CP=CPR*.0686                                                      GAS 2560
C DENSITY (DEN) IN LB/FT**3                                             GAS 2570
      DEN=22.03703*P/(Z*T)                                              GAS 2580
C **TRANSPORT PROPERTIES**                                              GAS 2590
C COLLISION CROSS SECTIONS                                              GAS 2600
      S2=31.4*1.E-16*(1.+(112./T))                                      GAS 2610
      SI2=(S2/3.1415927)**.5                                            GAS 2620
      SI4=(1.11676-(.01490* ALOG(1.-(1.-A23) **.5))-(.23654* ALOG       GAS 2630
     1(1.-(1.-A24)**.5))-(.11582* ALOG(1.-(1.-A25)**.5)))*1.0E-8        GAS 2640
      S4=3.1415927*(SI4)**2                                             GAS 2650
      S24=3.1415927*(SI24)**2                                           GAS 2660
      SI24=(SI2+SI4)/2.                                                 GAS 2670
      S47=9.40*1.0E-14/TSQRT                                            GAS 2680
      FI=ALOG(1.042*1.0E-7*TSQ*(P*X7 )**(-.5))                          GAS 2690
      S7=8.55644*1.0E-6*(1./TSQ)*FI                                     GAS 2700
      SIP4=(1.11676-(.0149*ALOG(1.-(1.-2.*A23)**.5))-(.23654*ALOG(1.-(1.GAS 2710
     1-2.*A24)**.5))-(.11582* ALOG(1.-(1.-2.*A25)**.5)))*1.0E-8         GAS 2720
      SP4=3.145927*(SIP4)**2                                            GAS 2730
      SIP24=(SI2+SIP4)/2.                                               GAS 2740
      SP24=3.145927*SIP24**2                                            GAS 2750
C COMPONENT MOL FRACTIONS FOR INDEPENDENT REACTIONS                     GAS 2760
      F1=1.+EE1                                                         GAS 2770
      F2=1.2+EE2                                                        GAS 2780
      F3=1.+EE3                                                         GAS 2790
      X1OD=(.2-EE1)/F1                                                  GAS 2800
      X2OD=.8/F1                                                        GAS 2810
      X3OD=2.*EE1/F1                                                    GAS 2820
      X2ND=(.8-EE2)/F2                                                  GAS 2830
      X3ND=.4/F2                                                        GAS 2840
      X4ND=2.*EE2/F2                                                    GAS 2850
      X4I=(1.-EE3)/F3                                                   GAS 2860
      X6I=EE3/F3                                                        GAS 2870
C MEAN FREE PATH RATIOS                                                 GAS 2880
```

```
      SS1=S24/S2                                                        GAS 2890
      SS2=S4/S2                                                         GAS 2900
      SS3=S7/S2                                                         GAS 2910
      SS4=S47/S2                                                        GAS 2920
      FP1OD=X1OD+X2OD*.9660918 +X3OD*SS1*.8164966                       GAS 2930
      FP2OD=X1OD*1.032796+X2OD+X3OD*SS1*.8528029                        GAS 2940
      FP3OD=X1OD*1.154701*SS1+X2ND*SS1*1.128152+X3OD*SS2                GAS 2950
      FP2ND=X2ND+X4ND*SS1*.8164966+X3ND*SS1*.8528029                    GAS 2960
      FP3ND=X2ND*SS1*1.128152+X4ND*SS2*.9660918+X3ND*SS2                GAS 2970
      FP4ND=X2ND*SS1*1.154701+X4ND*SS2+X3ND*SS2*1.032796                GAS 2980
      FP4I=X4I*SS2+X6I*SS2                                              GAS 2990
      FP6I=X4I*SS2+X6I*SS3                                              GAS 3000
      FP7I=X4I*SS4*1.414186+X6I*SS3*1.414186+X6I*SS3                    GAS 3010
C VISCOSTITES OF THE COMPONENTS FOR THE DIFFERENT REACTIONS              GAS 3020
      V1OD=1.054093*X1OD*1./FP1OD                                       GAS 3030
      V2OD=.9860133*X2OD*1./FP2OD                                       GAS 3040
      V3OD=.745356*X3OD*1./FP3OD                                        GAS 3050
      V2ND=.9860133*X2ND*1./FP2ND                                       GAS 3060
      V3ND=.745356*X3ND*1./FP3ND                                        GAS 3070
      V4ND=.6972167*X4ND*1./FP4ND                                       GAS 3080
      V4I=.6972167*X4I*1./FP4I                                          GAS 3090
      V6I=.6972167*X6I*1./FP6I                                          GAS 3100
      V7I=.4367848*1.0E-2*X6I*1./FP7I                                   GAS 3110
      VROD=V1OD+V2OD+V3OD                                               GAS 3120
      VRND=V2ND+V3ND+V4ND                                               GAS 3130
      VRI=V4I+V6I+V7I                                                   GAS 3140
      F4=EE2/(.2-EE1+EE2)                                               GAS 3150
      F5=2.*EE3/(.8-EE2+2.*EE3)                                         GAS 3160
      VR=VROD+(F4*(VRND-VROD))+(F5*(VRI-VRND))                          GAS 3170
C TOTAL VISCOSITY (V) IN LB/FT-SEC                                       GAS 3180
      V=VR*.9841838*1.0E-6*TSQRT/(1.+A22)                               GAS 3190
C CONDUCTIVITY DUE TO MOLECULAR COLLISIONS FOR DIFFERENT REACTIONS       GAS 3200
      G1=.2105263*CV1+.4736842                                          GAS 3210
      G2=.2105263*CV2+.4736842                                          GAS 3220
      G3=.2105263*CV3+.4736842                                          GAS 3230
      G4=.2105263*CV4+.4736842                                          GAS 3240
```

```
      G5=.2105363*CV6+.4736842
      G6=.2105363*CV7+.4736842
      XKNOD=(V1CD*.9*G1)+(V2CD*1.028571*G2)+(V3OD*1.8*G3)
      XKNNC=(V2ND*1.028571*G2)+(V3ND*1.8*G3)+(V4ND*2.057143*G4)
      XKNI=(V4I*2.057143*G4)+(V6I*2.C57143*G5)+(V7I*52416.0*G6)
      XKN=XKNCD+(F4*(XKNND-XKNCD))+(F5*(XKNI-XKNND))
C CONDUCTIVITY DUE TO CHECMICAL REACTIONS FCR THE DIFFERENT REACTIONS
      XKRCD=(.178637*(T*PK1)**2)/((SP24/(1.732051*S2))*(((X3OD+2.*X1OD)
     1**2)/(X3OD*X1CD)+(4.*X2OD/X3CC))+(X2OD/(1.414214*X1OD)))
      XKRND=(.178637*(T*PK2)**2)/((SP24/(1.732051*S2))*((((X4ND+2.*X2ND)
     1**2)/(X4ND*X2ND))+(X3NC/X2NC)) +(SP4*2.*X3ND/(S2*X4ND)))
      XKR1=(.178637*(T*PK34)**2)/(((.5*SP4/S2)+(.4347826*1.0E-2*S47/S2))
     1*((X4I+X6I)**2)/(X4I*X6I))
      XKOC=XKNOC+XKROD
      XKNC=XKNND+XKRND
      XKI=XKNI+XKR1
      XKR=XKCD+(F4*(XKND-XKCD))+(F5*(XKI-XKND))
C TOTAL THERMAL CCNDUCTIVITY (XK) IN BTU/FT-SEC-DEG R
      XK=XKR*((.3206522*1.0E-6*TSQRT)/(1.+A22))
C PRANDTL NUMBER (PR) DIMENSIONLESS
      PRN = .21C5263 * CPR * VR / XKR
      IF(I.EQ. 1) PRW = PRN
C FORM REQUIRED BY CALL STATEMENT
C
C      **  RHO UNITS SLUGS/FT**3
C      **  MU UNITS LBM/FT-SEC
C      **  RM UNITS LBF**2 SEC**3/FT**6
C
      MU (I) = V
      RHO(I)=DEN/32.174
C *** CALCULATE  THE MEAN MCLECULAR WT. ***
      REAL = 25C5C.*S      *Z / SR
      AMW(I)= GASC / REAL
C MASS FRACTIONS
      C(1,I) = X1      *32.00/AMW(I)
      C(2,I) = X2      *28.CO/AMW(I)
```

```
      C(3,I) = X3      *16.00/AMW(I)
      C(4,I) = X4      *14.C0/AMW(I)
      C(5,I) = X5      *16.C0/AMW(I)
      C(6,I) = X6      *14.00/AMW(I)
      C(7,I) = X7      /(1820.*AMW(I))
 2000 CONTINUE
      RDZ= RHO(NETA)
      MUDZ= MU(NETA)
C
C
      DO 40 I=KODE,NETA
C
C     **  NONDIMENSIONALIZE  RHO  AND  MU  **
C
      RHO(I) = RHC(I)/RDZ
      MU(I) = MU(I)/MUDZ
C
C
      XN1(I)=X1
      XN2(I)=X2
      XN3(I)=X3
      XN4(I)=X4
      XN7(I)=X7
   40 CONTINUE
  100 FORMAT(1X,9E14.6)
      RETURN
      END
```

```
      SUBROUTINE LRAD                                                   LRAD  10
C                                                                       LRAD  20
C                                                                       LRAD  30
C  ** THIS IS A DRIVER PROGRAM FOR SUBROUTINE TRANS WHICH CALCULATES ** LRAD  40
C     THE RADIATIVE FLUX DIVERGENCE THROUGH A ONE-DIMENSIONAL SLAB      LRAD  50
C     FOR A GIVEN TEMPERATURE AND SPECIES DISTRIBUTION                  LRAD  60
      COMMON /SFLUX/ QRI(3),CRR                                         LRAD  70
      COMMON /TRN/ YC( 5),NUT( 5), FNC(12, 5), FPC(12, 5),              LRAD  80
     1           FN(9, 5), FP(9, 5), LINES                              LRAD  90
      COMMON /MCLFRA/     X1( 5),X2( 5),    X3( 5),    X4( 5),          LRAD 100
     1                           X7( 5),    X8( 5),    X9( 5),  X10( 5),LRAD 110
     2                   X11( 5),   X12( 5),   X13( 5)                  LRAD 120
      COMMON /TEST/ETZ( 5),IEZ                                          LRAD 130
      COMMON /XY/  XI, DXI, ETA( 5),  DETA                              LRAD 140
      COMMON/PROP1/PI( 5),RHC( 5),T ( 5),AMW( 5),C(20,5)                LRAD 150
      COMMON/PROP4/PL,RCR,EI,FISO,QR,RLANDA,DELTAR      ,RU3,GAMMA      LRAD 160
      COMMON /FRSTRM/     U INF,     RINF,      UINF2,     R,  RE,  LXI,LRAD 170
     1                   ITM,        ITG,       NETA                    LRAD 180
      COMMON /NCN/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF                           LRAD 190
      COMMON /MAIN1/ NXI,  MAXG,  MAXM,  MAXS,  ICG,      MCONV,        LRAD 200
     1 GCONV, SCONV                                                     LRAD 210
      COMMON /RFLUX/                IRAD,  ITYPE,  E( 5)                LRAD 220
      COMMON /NUMDEN/ SNCC2( 5), SNDN2( 5), SNDO( 5), SNDN( 5),         LRAD 230
     1                                      SNDE( 5), SNDC( 5),         LRAD 240
     2               SNCH( 5), SNDC2( 5), SNDH2( 5), SNDCO( 5),         LRAD 250
     3               SNCC3( 5)                                          LRAD 260
      COMMON /RH/ DUD,DPHI,TD,RZB,PD,HD,HTOTAL ,VD                      LRAD 270
      COMMON /SPEC/     XMCL                                            LRAD 280
C                                                                       LRAD 290
      DIMENSION DENS( 5,11), TIT(20),FRAC ( 5,11)                       LRAD 300
      EQUIVALENCE (SNDO2(1),DENS(1,1))                                  LRAD 310
      EQUIVALENCE (X1(1),FRAC(1,1))                                     LRAD 320
C                                                                       LRAD 330
C  ** INDEX IS NUMBER GIVEN SPECIE FOR USE IN STORING ARRAYS **         LRAD 340
C     1 = O2      4 = O       7 = H       10 = CO                       LRAD 350
C     2 = N2      5 = E-      8 = C2      11 = C3                       LRAD 360
```

```
C       3 = O          6 = C          9 = H2
C
      IEZ=NETA-1
      NI=NETA-1
      T(NETA) = TD
      DO 15I=1,NI
      T(I)=TD
      DO 12K=1,11
   12 FRAC(I,K)=FRAC(NETA,K)
      AMW(I)=AMW(NETA)
      RHO(I)=RHO(NETA)
   15 CONTINUE
C
  170 CALL TRANS(1)
C
      CALL TRANS2
      IF(IDG.EQ.0)GO TO 20
C
      WRITE (6,113) (QRI(I),I=1,3)
  113 FORMAT (1H1,32HTOTAL RADIATIVE FLUX - WATTS/CM3 // 3E15.6)
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SND(I,K)
      COMMON /MCLFRA/    X1( 5),X2( 5),   X3( 5),   X4( 5),
     1                   X7( 5),  X8( 5),  X9( 5),  X10( 5),
     2                   X11( 5),  X12( 5), X13 ( 5)
      COMMCN/PRCP1/PI( 5),  R( 5),T ( 5),ANW( 5),C(20,5)
      COMMON /RFLUX/              IRAD,  ITYPE,  E( 5)
      COMMON /NCN/RDZ,NUCZ,RMDZ,AKNF,HNF,CPNF
      COMMON /NUMDEN/ SNCC2( 5), SNDN2( 5), SNDO( 5), SNDN( 5),
     1                                   SNDE( 5), SNDC( 5),
     2                 SNDH( 5), SNDC2( 5), SNDH2( 5), SNDCO( 5),
     3                 SNCC3( 5)
C
C  **  CALCULATE SPECIE NUMBER DENSITIES BASED ON MOLE FRACTIONS   **
C
      RRUOKM=3.11E+23 * R(I) * RDZ/ANW(I)
      SNDO2(I)=RRUOKM * X1(I)
      SNDN2(I)=RRUOKM * X2(I)
      SNDO(I)=RRUCKM * X3(I)
      SNDN(I)=RRUCKM * X4(I)
      SNDE(I)=RRUOKM * X7(I)
      SNDC(I)=RRUCKM * X8(I)
      SNDH(I)=RRUOKM * X9(I)
      SNCC2(I)=RRUOKM * X10(I)
      SNDH2(I)=RRUOKM * X11(I)
      SNDCC(I)=RRUOKM * X12(I)
      SNCC3(I)=RRUOKM * X13(I)
      RETURN
      END
```

```
      BLOCK DATA
      COMMON /FINV/ NHVL,NIHVC,FHVC(12),CJ(9),HVJ(9),ZKZ
      COMMON /XY/  XI, DXI, ETA( 5),  DETA
      COMMON /TEST/ETZ( 5),IEZ
      COMMON /TRN/ YD( 5),NUT( 5), FMC(12, 5), FPC(12, 5),
     1             FM(9, 5), FP(9, 5), LINES
      DATA NHVL /9/, NIHVC /12/
      DATA FHVC /5.0,  6.0,  7.0,  8.0, 9.0,  10.0,  10.8, 11.1,
     1           12.0, 13.4, 14.3, 2C.C/
      DATA DJ   /C.6,  2.2,  1.5,  1.65, 1.4,  1.0,   1.2,  1.4,
     1           1.C/
      DATA HVJ  /1.3,  2.7,  5.75,  7.57, 9.1, 10.4,  11.4, 12.7,
     1           13.9/
      DATA ZKZ  /7.26E-16/
      CATA ETA / C.C,0.25,0.50,0.75,1.CC/
      CATA ETZ / C.C,0.25,C.50,0.75,1.0C/
      CATA YD  / C.C,0.25,C.50,0.75,1.CC/
      END
```

```
      SUBROUTINE RADIN
C
C  **  THIS SUBROUTINE INITIALIZES UNCHANGING CONSTANTS
C      USED IN SUBROUTINE TRANS   **
C
      COMMON /DBUG/ GLC( 5), QCL( 5), GLL( 5), DCN( 5), QCC( 5),
     1              BEEC(12, 5),   FNUC(12, 5),   EM(12, 5),
     2              EP(12, 5),     TAUC(12, 5),   BEEL(9, 5),
     3              QCCP(12),      WNM(9, 5),     GNM(9, 5),
     4              EEM(9, 5),     XLMM(9, 5),    GLCP(9),
     5              QCLP(9),       GLLP(9),       DELTA,     IY,    IYY,
     6              WPP(9, 5),     GPP(9, 5),     EEP(9, 5),
     7              XLPP(9, 5),    FG(9,4),       GP(9,4),
     8              WN(9,4),       FNUL(9, 5),    SSM(9,4, 5),
     9              GGM(9,4, 5),   ETAM(9,4, 5),  SBM(9,4, 5),
     A              TAUL(9, 5)
C  **  GROUP 1   **
       WN(1,1)=0.
       FG(1,1)=0.
       GP(1,1)=0.
       WN(1,2)=18.
       WN(1,3)=15.
       WN(1,4)=5.
C  **  GROUP 2   **
       WN(2,1)=3.C
       WN(2,2)=5.0
       WN(2,3)=11.C
       WN(2,4)=1C.
C  **  GROUP 3   **
       WN(3,1)=0.
       FG(3,1)=0.
       GP(3,1)=0.
       WN(3,2)=2.C
       WN(3,3)=0.
       FG(3,3)=0.
       GP(3,3)=0.
```

```
      WN(3,4)=0.                                                        RADI 370
      FG(3,4)=0.                                                        RADI 380
      GP(3,4)=0.                                                        RADI 390
C  **  GROUP 4   **                                                     RADI 400
      WN(4,1)=0.                                                        RADI 410
      FG(4,1)=0.                                                        RADI 420
      GP(4,1)=0.                                                        RADI 430
      WN(4,2)=8.0                                                       RADI 440
      WN(4,3)=2.0                                                       RADI 450
      WN(4,4)=0.                                                        RADI 460
      FG(4,4)=0.                                                        RADI 470
      GP(4,4)=0.                                                        RADI 480
C  **  GROUP 5   **                                                     RADI 490
      WN(5,1)=0.                                                        RADI 500
      FG(5,1)=0.                                                        RADI 510
      GP(5,1)=0.                                                        RADI 520
      WN(5,2)=14.                                                       RADI 530
      WN(5,3)=4.0                                                       RADI 540
      WN(5,4)=1.0                                                       RADI 550
C  **  GROUP 6   **                                                     RADI 560
      WN(6,1)=1.0                                                       RADI 570
      WN(6,2)=4.0                                                       RADI 580
      WN(6,3)=13.0                                                      RADI 590
      WN(6,4)=2.0                                                       RADI 600
C  **  GROUP 7   **                                                     RADI 610
      WN(7,1)=0.                                                        RADI 620
      FG(7,1)=0.                                                        RADI 630
      GP(7,1)=0.                                                        RADI 640
      WN(7,2)=6.0                                                       RADI 650
      WN(7,3)=14.0                                                      RADI 660
      WN(7,4)=3.0                                                       RADI 670
C  **  GROUP 8   **                                                     RADI 680
      WN(8,1)=2.0                                                       RADI 690
      WN(8,2)=2.0                                                       RADI 700
      WN(8,3)=11.                                                       RADI 710
      WN(8,4)=15.                                                       RADI 720
```

```
C   **  GROUP 9   **                                    RADI 730
       WN(9,1)=0.                                       RADI 740
       FG(9,1)=0.                                       RADI 750
       GP(9,1)=0.                                       RADI 760
       WN(9,2)=1.0                                      RADI 770
       WN(9,3)=11.                                      RADI 780
       WN(9,4)=10.                                      RADI 790
       RETURN                                           RADI 800
       END                                              RADI 810
```

```
      SUBROUTINE TRANS (ISW)
C
C-----THIS IS A MODIFIED VERSION OF SUBRCUTINE TRANS FROM K WILSON
C     TRANS IS COCUMENTED IN  LMSC-687209 APRIL 69  ----------------
C
      COMMON /ZPI/ ZPO(6), ZPN(6),ZPH(2),  ZPC(7)
      COMMON /FINV/ NHVL,NIHVC,FHVC(12),CJ(9),HVJ(9),ZKZ
      COMMON /SFLUX/ GRI(3),GRH
      COMMON /TRN/ YD( 5),NUT( 5), FXC(12, 5), FPC(12, 5),
     1            FM(9, 5), FP(9, 5), LINES
      COMMON /MOLFRA/    X1( 5),X2( 5),    X3( 5),    X4( 5),
     1                          X7( 5),  X8( 5),  X9( 5),  X10( 5),
     2                  X11( 5),  X12( 5),  X13( 5)
      COMMON /XY/  XI, DXI, ETA( 5),  DETA
      COMMON /FRSTRM/    U INF,     RINF,      UINF2,     XL,  RE,  LXI,
     1                   ITM,     ITG,       NES
      COMMON /NON/RDZ,MUDZ,RMDZ,AKNF,HNF,CPNF
      COMMON /MAIN1/ NXI,  MAXG,  MAXM,  MAXS,  IDG,      MCONV,
     1  GCONV, SCONV
      COMMON/PROP1/PI( 5),  R( 5),T ( 5),AMW( 5),C(20,5)
      COMMON/PROP4/PL,RCR,EI,FISC,QR,RLANDA,DELTAR     ,RU3,GAMMA
      COMMON /RFLUX/              IRAC,  ITYPE,  E( 5)
      COMMON /TEST/ETZ( 5),IEZ
      COMMON /NUMDEN/ SNCC2( 5), SNDN2( 5), SNDO( 5), SNDN( 5),
     1                                      SNDE( 5), SNDC( 5),
     2                SNCH( 5), SNCC2( 5), SNDH2( 5), SNDCO( 5),
     3                SNCC3( 5)
      COMMON /DBUG/ QLC( 5), QCL( 5), QLL( 5), DCN( 5), OCC( 5),
     1             DEEC(12, 5),    FNUC(12, 5),    EM(12, 5),
     2             EP(12, 5),      TAUC(12, 5),    BEEL(9, 5),
     3             QCCP(12),       WMM(9, 5),      GMM(9, 5),
     4             EEM(9, 5),      XLMM(9, 5),     QLCP(9),
     5             QCLP(9),        CLLP(9),        DELTA,     IY,   IYY,
     6             WPP(9, 5),      GPP(9, 5),      EEP(9, 5),
     7             XLPP(9, 5),     FG(9,4),        GP(9,4),
     8             WN(9,4),        FNUL(9, 5),     SSM(9,4, 5),
```

```
     9               GGM(9,4, 5),   ETAM(9,4, 5),  SBM(9,4, 5),
     A               TAUL(9, 5)
      COMMON /SPEC/     XMCL
      DIMENSION  XKT( 5),          CC( 5)
C
C **   BAND AVERAGE ABSCRPTICN CROSS SECTICN (EQ.A2)   **
C
      SIGMA(ZH,ZA,ZE,ZG)=   ((5.0E+C3*T1*ZG*ZKZ)/BE) * (EXP(ZDL/T1)
     1                      *ZH*(ZA+ZB* (ZH**2)/3.0) +
     2                      T1 * (ZA+2.0*ZB*T12) -T1*EXP((ZH-ZHVP)/T1)
     3                      *(ZA+ZE*(ZHVF-ZH)**2) -T1*EXP((ZH-ZHVP)/T1)
     4                      *2.0*ZE*T1*(ZHVP-ZH+T1))
      SIGMA2(ZH,ZG,ZE,ZY)=7.26E-16*T1*ZG*EXP((-ZE+ZY+ZDL)/T1)/ZH**3
      GAMMA(ZX)=(1.C+(1.5707963*ZX)**1.25)**(-0.4)
      XLAMB(ZX)=(1.C+ZX*EXP(-ZX))/SQRT(1.0+6.283185 *ZX)
C
C **   W(GROUP)/D CCRRELATION (EQ.88)   **
C
      PHI1(ZX)=(ATAN(1.570796 *ZX)/1.57C796 )
C
C **   FLUX DIVERGENCE OVERLAPPING FUNCTICN (EQ.92)   **
C
      PHI2(ZX)=EXP(-ZX)
C
      CALL RADIN
      ZHVP=5.0
      YI=0.0
      IF (MF.NE.C) GO TO 2000
      XNE=SNDE(NES)
      GO TO 2010
 2000 RRUOKM=3.11E+23 * R(NES) * RDZ / AMW(NES)
      XNE=X7(NES) * RRUCKM
 2010 FNE=(4.71E-6 * XNE**(2.0/7.C))/((T(NES)/11606.)**(1.0/7.0))
      ZDL=AMIN1(0.2C,FNE)
C
C **   DEBUG PRINT   **
```

```
C
      IF (IDG.NE.0) CALL BUGPR (1)
      DELTA = PL
      IF(IDG.NE.0)CALL BUGPR (2)
      DO 91 L=1.NES
      XKT(L)=T(L)/11606.
      T1=XKT(L)
      IF (MF.NE.C) CALL SND(L.1)
C
C **   PARTITION FUNCTIONS FOR H. C. N. C   **
C
   94 IF(T(L).GT.15000.) GO TO 6
C
C **   LOW  TEMPERATURE   **
C
      SUMH=2.0
      SUMC=9.0   +   5.0 * EXP(-1.264/T1) + EXP(-2.684/T1) +
     1               5.0 * EXP(-4.183/T1)
      SUMN=4.0 + 10.0 *EXP(-2.384/T1) + 6.0 *EXP(-3.576/T1)
      SUMO= 9.0 + 5.0 * EXP(-1.975/T1)
      GO TO 7
C
C **   HIGH TEMPERATURE   **
C
    6 SUMH=2.0
      SUMC=2.71818  +  6.40677 * T(L)/1.0E4 -0.45466 * (T(L)/1.0E4)**2
      SUMN=5.938216 - 0.225593 * T(L)/1.0E3 + 0.015408 * (T(L)/1.0E3)**2
      SUMO=11.79563 -0.317964 * T(L)/1.0E3 + 0.013765 * (T(L)/1.0E3)**2
    7 CONTINUE
      T12=T1**2
      GH = 6.4994
      DO 5 K=1.12
      GF=FHVC(K)/T1
      GHM=GH
      GH=EXP(-GF)  *GF  *  (GF**2 + 3.0 *GF  +6.0  + 6.0/GF)
C
```

```
C **   PLANK MEAN ABSORPTION COEFFICIENT FOR BAND INTERVALS (EQ.A3)  **
C
      BEEC(K,L)=5.04E3  *  (T12**2)  *  (GHM-GH)
      BE=BEEC(K,L)
C
C **   ABSORPTION CROSS SECTIONS ' **
C      SOECIES --
C                       N       N2        CO
C                       O       C2
C                       C       C2
C                       H       H2        C3
C
      SGH=0.
      SGN=0.
      SGC=0.
      SGO=0.
      SGCO=0.
      SGC2=0.
      SGO2=0.
      SGN2=0.
      SGH2=0.
      SGC3=0.
      SGCS=0.0
      GO TO (581,582,583,584,585,586,587,588,589,590,591,592),K
  581 SGH=SIGMA(2.4,1.0,0.0,1.0)  *  EXP(-13.56/T1)
      SGC=SIGMA(3.78,  0.3,   0.0488,  1.33)  * EXP(-11.26/T1)
      SGN=SIGMA(4.22,  0.24,  0.0426,  4.5) * EXP(-14.54/T1)
      SGO=SIGMA(4.22,  0.24,  0.0426,   .888889)  * EXP(-13.61/T1)
      SGCS=3.4E-12
      GO TO 38
  582 ZZHV=5.5
      SGC2=8.0E-18 * EXP(-0.5/T1)  +  3.0E-18
      SGC3=4.0E-18
      SGCS=3.4E-12
  593 CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)
      SGC=SIGMA2(ZZHV, 1.33,  11.26,  3.78) * ZZC + SGC
```

```
      SGN=SIGMA2 (ZZHV,4.50,  14.54,  4.22) * ZZN                       TRAN1450
  594 SGO=SIGMA2 (ZZHV, .889,  13.61,  4.22) * ZZO                      TRAN1460
  595 SGH=SIGMA2 (ZZHV, 1.00,  13.56,  2.40)                            TRAN1470
      GO TO 38                                                          TRAN1480
  583 ZZHV=6.5                                                          TRAN1490
      SGC2=1.0E-18                                                      TRAN1500
      SGCC=3.0E-18 * EXP(-0.7/T1)                                       TRAN1510
      GO TO 593                                                         TRAN1520
  584 ZZHV=7.5                                                          TRAN1530
      SGC=5.0E-17  * EXP(-4.18/T1)/SUMC                                 TRAN1540
      SGCO=1.9E-17  * EXP(-0.5/T1)                                      TRAN1550
      SGO2=6.0E-19                                                      TRAN1560
      GO TO 593                                                         TRAN1570
  585 ZZHV=8.5                                                          TRAN1580
      SGC=5.0E-17 *EXP(-4.18/T1)/SUMC  +                                TRAN1590
     1    2.2E-17* EXP(-2.68/T1)/SUMC                                   TRAN1600
      SGCO=2.5E-17                                                      TRAN1610
      SGO2=2.0E-19                                                      TRAN1620
      GO TO 593                                                         TRAN1630
  586 ZZHV=9.5                                                          TRAN1640
      SGC=5.0E-17 * EXP(-4.18/T1)/SUMC  +                               TRAN1650
     1    2.2E-17 * EXP(-2.68/T1)/SUMC                                  TRAN1660
      SGCO=5.0E-18                                                      TRAN1670
      SGO2=1.0E-18                                                      TRAN1680
      GO TO 593                                                         TRAN1690
  587 SGN=3.2E-18 *T1 *EXP(-10.2/T1)/SUMN                               TRAN1700
      SGO2=6.0E-19                                                      TRAN1710
      ZZHV=10.4                                                         TRAN1720
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1730
  596 SGC=(8.5E-17 *EXP(-1.26/T1)  +  2.2E-17 * EXP(-2.75/T1)           TRAN1740
     1    +  5.0E-17 * EXP(-4.18/T1))/SUMC                              TRAN1750
      GO TO 594                                                         TRAN1760
  588 ZZHV=10.9                                                         TRAN1770
      CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)                                    TRAN1780
      SGN=(5.16E-17  *EXP(-3.50/T1))/SUMN                               TRAN1790
      GO TO 596                                                         TRAN1800
```

```
 589 ZZHV=11.6
     CALL ZHV(ZZHV,ZZO,ZZN,ZZI,ZZC)
     SGN2=1.0E-18
     SGN=(5.16E-17 *  EXP(-3.50))/SUMN
 598 SGC=(9.9E-17  +  8.5E-17 * EXP(-1.26/T1)  +2.2E-17 * EXP(-2.75/T1)
    1      +  5.0E-17 * EXP(-4.18/T1))/SUMC
     IF (K.LT.11) GO TO 594
     GO TO 38
 590 ZZHV=12.7
     CALL ZHV  (ZZHV,ZZC,ZZN,ZZI,ZZC)
     SGN2=2.0E-18
 599 SGN=(6.4E-17 * EXP(-2.30/T1)  +  5.16E-17 * EXP(-3.50/T1))/SUMN
    1      +  SGN
     GO TO 598
 591 SGH=1.18E-17/SUMH
     SGC=3.6E-17/SUMO
     SGN2=1.0E-17
     GO TO 599
 592 SGN=3.6E-17/SUMN
     SGN2=1.0E-18
     GO TO 599
 38  CONTINUE
     FMUC(K,L)= SNDH(L)*SGH + SNDC(L)*SGC + SNDN(L)*SGN + SNDO(L)*SGO
    1           + XMOL *    (SNDN2(L)*SGN2 + SNDO2(L)*SGO2 +
    2           SNDC2(L)*SGC2 + SNDH2(L)*SGH2 + SNDCO(L)*SGCO +
    3           SNDC3(L)*SGC3)
     IF (L.GT.1) GO TO 8
     TAUC(K,L)=0.
     GO TO 5
   8 TAUC(K,L)=TAUC(K,L-1)+(YD(L)-YD(L-1))*
    1     (FMUC(K,L-1)+FMUC(K,L)) * DELTA
   5 CONTINUE
     IF (LINES.EQ.0) GO TO 91
C
C **   FRACTIONAL POPULATION STATES FOR H, N, O, C  **
C
```

```
      CALL ZP (T1,SUMN,SUMC,SUMH,SUMC)                                  TRAN2170
C **   CALCULATICN CF PARAMETERS FCR 9 LINE GROUPES  **                 TRAN2180
C      WN -- NUMBER OF LINES                                            TRAN2190
C      FG -- EFFECTIVE F-NUMBER                                         TRAN2200
C      GP -- EFFECTIVE HALF-WIDTH                                       TRAN2210
C                                                                       TRAN2220
C GROUP 1                                                               TRAN2230
      FG(1,2)=(1.02 * ZPC(5)  +  .795 * ZPC(6)  +  0.114 * ZPC(7))      TRAN2240
     1   /WN(1,2)                                                       TRAN2250
      GP(1,2)=(8.16E-11 * SQRT(ZPC(5))  +  1.25E-10 * SQRT(ZPC(6))      TRAN2260
     1     +2.55E-10 * SCRT(ZPC(7)))**2 /(FG(1,2)* WN(1,2)**2)          TRAN2270
      FG(1,3)=(1.040 * ZPN(4)  +  1.29 * ZPN(5)  +  0.00 *ZPN(6))       TRAN2280
     1        /WN(1,3)                                                  TRAN2290
      GP(1,3)=(6.65E-11 * SQRT(ZPN(4))  +  1.71E-10 * SQRT(ZPN(5))      TRAN2300
     1     +  C.COE-10 * SCRT(ZPN(6)))**2/(FG(1,3) * WN(1,3)**2)        TRAN2310
      FG(1,4)=(1.CO * ZPC(5)  +  .978 * ZPO(6))/WN(1,4)                 TRAN2320
      GP(1,4)=(3.90E-11 * SQRT(ZPC(5))  +  9.68E-11 * SQRT(ZPO(6)))**2  TRAN2330
     1        /(FG(1,4) * WN(1,4)**2)                                   TRAN2340
      FMUL(1,L)=FMUC(1,L)                                               TRAN2350
C GROUP 2                                                               TRAN2360
      FG(2,1)=0.8C5 * ZPH(2)/WN(2,1)                                    TRAN2370
      GP(2,1)=2.37E-10 * 2.37E-10 * ZPH(2)/(FG(2,1) * WN(2,1)**2)       TRAN2380
      FG(2,2)=(C.COE-2 * ZPC(5)  +  6.71E-2 * ZPC(6))/WN(2,2)           TRAN2390
      GP(2,2)=(0.COE-12 * SCRT(ZPC(5))  +  7.15E-11 * SQRT(ZPC(6)))**2  TRAN2400
     1        /(FG(2,2) * WN(2,2)**2)                                   TRAN2410
      FG(2,3)=(C.C47* ZPN(4)  +  2.85E-2 * ZPN(5))/WN(2,3)              TRAN2420
      GP(2,3)=(1.11E-10 * SQRT(ZPN(4))  +  6.07E-11 * SQRT(ZPN(5)))**2  TRAN2430
     1        /(FG(2,3) * WN(2,3)**2)                                   TRAN2440
      FG(2,4)=(.C217 * ZPO(4)  +  8.25E-2 * ZPO(5))/WN(2,4)             TRAN2450
      GP(2,4)=(2.61E-11 * SQRT(ZPC(4))  +  7.19E-11 * SQRT(ZPO(5)))**2  TRAN2460
     1   /(FG(2,4) * WN(2,4)**2)                                        TRAN2470
      FMUL(2,L)=FMUC(1,L)                                               TRAN2480
C  GRCUP 3                                                              TRAN2490
      FG(3,2)=(7.29E-2 * ZPC(2)  +  6.76E-2 *ZPC(3))/WN(3,2)            TRAN2500
      GP(3,2)=(9.08E-12 * SCRT(ZPC(2))  +  8.75E-12 * SQRT(ZPC(3)))**2  TRAN2510
     1        /(FG(3,2) * WN(3,2)**2)                                   TRAN2520
```

```
      FMUL(3.L)=FMUC(2.L)
C   GROUP 4
      FG(4.2)=(1.05 * ZPC(1)  +  1.10E-2 *ZPC(2)  +  0.150 * ZPC(3))
     1        /WN(4.2)
      GP(4.2)=(9.57E-12 * SQRT(ZPC(1))  +  4.86E-12 * SQRT(ZPC(2))
     1        +  5.93E-10 * SQRT(ZPC(3)))**2/(FG(4.2) * WN(4.2)**2)
      FG(4.3)=( 7.40E-2  * ZPN(2)  +  6.34E-2 * ZPN(3))/WN(4.3)
      GP(4.3)=(8.22E-12 * SQRT(ZPN(2))  +  7.60E-12 * SQRT(ZPN(3)))**2
     1        /(FG(4.3) * WN(4.3)**2)
      FMUL(4.L)=FMUC(4.L)
C   GROUP 5
      FG(5.2)=(0.329 * ZPC(1)  +  0.118 * ZPC(2)  +  0.226 * ZPC(4))
     1        /WN(5.2)
      GP(5.2)=(3.65E-11 * SQRT(ZPC(1))  +  5.77E-10 * SQRT(ZPC(2))
     1        +  6.56E-11 *  SQRT(ZPC(4)))**2/(FG(5.2) * WN(5.2)**2)
      FG(5.3)=0.108 * ZPN(3)/WN(5.3)
      GP(5.3)=3.09E-11 * 3.09E-11 * ZPN(3)/(FG(5.3) * WN(5.3)**2)
      FG(5.4)=4.71E-2 * ZPO(1)/WN(5.4)
      GP(5.4)=5.08E-12 * 5.08E-12 * ZPO(1)/(FG(5.4) * WN(5.4)**2)
      FMUL(5.L)=FMUC(6.L)
C   GROUP 6
      FG(6.1)=0.416 * ZPH(1)/WN(6.1)
      GP(6.1)=3.02E-11 * 3.02E-11 * ZPH(1)/(FG(6.1)* WN(6.1)**2)
      FG(6.2)=8.65E-2 * ZPC(1)/WN(6.2)
      GP(6.2)=2.35E-10 * 2.35E-10 * ZPC(1)/(FG(6.2) * WN(6.2)**2)
      FG(6.3)=(0.184 * ZPN(1)  +  0.290 * ZPN(2)  +  8.52E-2 * ZPN(3))
     1        /WN(6.3)
      GP(6.3)=(1.07E-11 * SQRT (ZPN(1))  +  4.28E-11 * SQRT(ZPN(2))
     1        +  2.09E-10 * SQRT(ZPN(3)))**2/(FG(6.3) * WN(6.3)**2)
      FG(6.4)=(.120 * ZPO(2)  +  0.151 * ZPC(3))/WN(6.4)
      GP(6.4)=(8.85E-12 * SQRT(ZPO(2))  +  9.93E-12 * SQRT(ZPO(3)))**2
     1        /(FG(6.4) * WN(6.4)**2)
      FMUL(6.L)=FMUC(7.L)
C    GROUP  7
      FG(7.2)=(4.51E-2 * ZPC(1)  +  0.705 * ZPC(2))/WN(7.2)
      GP(7.2)=(6.07E-10 * SQRT(ZPC(1))  +  2.10E-10 * SQRT(ZPC(2)))**2
```

```
     1        /(FG(7.2) * WN(7.2)**2)                                       TRAN2890
      FG(7.3)=(0.454 * ZPN(1)  +  9.66E-2 * ZPN(2)                          TRAN2900
     1        +  C.178 * ZPN(3))/WN(7.3)                                    TRAN2910
      GP(7.3)=(2.71E-12 * SQRT(ZPN(1))  +  2.34E-10 * SQRT(ZPN(2))          TRAN2920
     1        +  2.46E-11 * SQRT(ZPN(3)))**2/(FG(7.3)* WN(7.3)**2)          TRAN2930
      FG(7.4)=4.23E-2 * ZPO(3)/WN(7.4)                                      TRAN294C
      GP(7.4)=2.52E-11 * 2.52E-11 * ZPO(3)/(FG(7.4) * WN(7.4)**2)           TRAN295C
      FMUL(7.L)=FMUC(9.L)                                                   TRAN2960
C   GROUP  8                                                                TRAN2970
      FG(8.1)=0.108 * ZPH(1)/WN(8.1)                                        TRAN2980
      GP(8.1)=1.32E-10  *  1.32E-10 * ZPH(1)                                TRAN299C
     1        /(FG(8.1) * WN(8.1)**2)                                       TRAN3C00
      FG(8.2)=(C.379 * ZPC(1)  +  1.05 * ZPC(3))/WN(8.2)                    TRAN3010
      GP(8.2)=(1.95E-11 * SQRT(ZPC(1))  +  1.27E-10 * SQRT(ZPC(3)))**2      TRAN3020
     1        /(FG(8.2) * WN(8.2)**2)                                       TRAN303C
      FG(8.3)=(C.155 * ZPN(1)  +  0.142*ZPN(2)  +  3.75E-2 * ZPN(3))        TRAN3040
     1        /WN(8.3)                                                      TRAN3050
      GP(8.3)=(2.98E-11 * SQRT(ZPN(1))  +  7.08E-11 * SQRT(ZPN(2))          TRAN306C
     1        +  1.33E-1C * SQRT(ZPN(3)))**2/(FG(8.3) * WN(8.3)**2)         TRAN307C
      FG(8.4)=(0.146 * ZPC(1)  +  8.61E-2*ZPO(2)                            TRAN3080
     1        +  9.33E-2 * ZPO(3))/WN(8.4)                                  TRAN3090
      GP(8.4)=(1.97E-10 * SQRT(ZPO(1))  +  1.80E-11 * SQRT(ZPO(2))          TRAN310C
     1        +  8.13E-11 * SQRT(ZPC(3)))**2/(FG(8.4) * WN(8.4)**2)         TRAN3110
      FMUL(8.L)=FMUC(10.L)                                                  TRAN3120
C   GROUP  9                                                                TRAN3130
      FG(9.2)=2.95 * ZPC(2)/WN(9.2)                                         TRAN314C
      GP(9.2)=5.85E-12 * 5.85E-12 * ZPC(2)/(FG(9.2) * WN(9.2)**2)           TRAN315C
      FG(9.3)=(C.224 * ZPN(1)  +  2.92E-2 * ZPN(2))/WN(9.3)                 TRAN3160
      GP(9.3)=(3.41E-10 * SQRT(ZPN(1))  +  1.48E-10 * SQRT(ZPN(2)))**2      TRAN317C
     1        /(FG(9.3) * WN(9.3)**2)                                       TRAN3180
      FG(9.4)=(5.24E-2 * ZPO(1)  +  7.22E-2 * ZPO(2)                        TRAN3190
     1        +  6.C4E-2 * ZPC(3))/WN(9.4)                                  TRAN3200
      GP(9.4)=(5.76E-12 * SQRT(ZPC(1))  +  7.20E-11 * SQRT(ZPO(2))          TRAN3210
     1        +  8.C5E-11 * SQRT(ZPC(3)))**2/(FG(9.4) * WN(9.4)**2)         TRAN3220
      FMUL(9.L)=FMUC(11.L)                                                  TRAN3230
C                                                                           TRAN3240
```

```
C **   PLANCK FUNCTION  **                                                  TRAN3250
C                                                                           TRAN3260
      DO 9 J=1,NHVL                                                         TRAN3270
      DEEL(J,L)=5.04E3 * HVJ(J)**3 / (EXP(HVJ(J)/T1)  -  1.0)               TRAN3280
C                                                                           TRAN3290
C **   INDUCED EMISSION FACTOR (EQ 81)  **                                  TRAN3300
C                                                                           TRAN3310
      SSM(J,1,L)=1.10E-16*SNDH (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,1)          TRAN3320
      SSM(J,2,L)=1.10E-16*SNDC (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,2)          TRAN3330
      SSM(J,3,L)=1.10E-16*SNDN (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,3)          TRAN3340
      SSM(J,4,L)=1.10E-16*SNDO (L)*(1.0-EXP(-HVJ(J)/T1)) * FG(J,4)          TRAN3350
      DO 10 M=1,4                                                           TRAN3360
      GGM(J,M,L)=GP(J,M) * SNDE(L)   * (T(L)/1.0E4)**0.25                   TRAN3370
     1         +  1.0E-6                                                    TRAN3380
      IF(L.GT.1) GO TO 11                                                   TRAN3390
      ETAM(J,M,1)=0.                                                        TRAN3400
      SBM (J,M,1)=0.                                                        TRAN3410
      GO TO 10                                                              TRAN3420
   11 ETAM(J,M,L)=ETAM(J,M,L-1)+  (YD(L)-YD(L-1))                           TRAN3430
     1         *(SSM(J,M,L-1) * GGM(J,M,L-1)  +  SSM(J,M,L) * GGM(J,M,L))TRAN3440
     2         * DELTA/3.14159265                                           TRAN3450
      SBM(J,M,L)=SBM(J,M,L-1)  +  (YD(L)-YD(L-1))                           TRAN3460
     1         * (SSM(J,M,L-1)+SSM(J,M,L)) * DELTA                          TRAN3470
   10 CONTINUE                                                              TRAN3480
      IF (L.GT.1) GO TO 12                                                  TRAN3490
      TAUL(J,1)=0.                                                          TRAN3500
      GO TO 9                                                               TRAN3510
   12 TAUL(J,L)=TAUL(J,L-1)  +  (YD(L)-YD(L-1))                             TRAN3520
     1         * (FMUL(J,L-1)+FMUL(J,L))  * DELTA                           TRAN3530
    9 CONTINUE                                                              TRAN3540
      IF (IDG.NE.99) GO TO 91                                               TRAN3550
      CALL BUGPR (7)                                                        TRAN3560
C                                                                           TRAN3570
   91 CONTINUE                                                              TRAN3580
      IEZ=IEZ+1                                                             TRAN3590
      ETZ(IEZ)=1.0                                                          TRAN3600
```

```
C
C **    CONTINUUM - CONTINUUM FLUX DIVERGENCE CALCULATION   **
C
      DO 300 K=1,IEZ
      DO 31 LK=1,NES
      I=LK
      NUT(K)=I
      IF (ABS(ETZ(K)-ETA(LK)) - 1.0E-5) 300,300,31
   31 CONTINUE
  300 CONTINUE
      DO 1612 J=1,9
      QCLP(J)=0.
      QLCP(J)=0.
      QLLP(J)=0.
      DO 1612 L=1,NES
      FM(J,L)=0.
 1612 FP(J,L)=0.
      DO 1613 L=1,IEZ
      QCL(L)=0.
      QLC(L)=0.
 1613 QLL(L)=0.
      DO 49 IYY=1,IEZ
      IY=NUT(IYY)
      DO 20 K=1,12
      FMC(K,IY)=0.
      FPC(K,IY)=0.
      IF (IY.EQ.1) GO TO 44
      DO 40 L=1,IY
C
C **    MINUS EMISSIVITY FUNCTION (EQ 47)   *
C
      EM(K,L)=1.0  -  EXP(TAUC(K,L)-TAUC(K,IY))
      IF (L.EQ.1) GO TO 40
C
C **    MINUS CONTINUUM FLUX (EQ 46)   **
C
```

```
      FMC(K,IY)=FMC(K,IY)   -   (EM(K,L)-EM(K,L-1))
     1          * (BEEC(K,L-1)+BEEC(K,L))/2.
   40 CONTINUE
   44 IF (IY.EQ.NES ) GO TO 41
      DO 42 L=IY,NES
C
C **   POSITIVE EMISSIVITY FUNCTICN (EQ 47)   **
C
      EP(K,L)=1.0  -   EXP(TAUC(K,IY)-TAUC(K,L))
      IF (L.EQ.IY) GC TO 42
C
C **   POSITIVE EMISSIVITY CONTINLUM FLUX (EQ 46)   **
C
      FPC(K,IY)=FPC(K,IY)   +   (EP(K,L)-EP(K,L-1))
     1          * (BEEC(K,L-1)+BEEC(K,L))/2.
   42 CONTINUE
C
C **   POSITIVE EMISSIVITY CONTINUUM FLUXDIVERGENCE (EQ 51)   **
C
   41 QCCP(K)=6.2831853 * FMUC(K,IY) *
     1          (FMC(K,IY)   +   FPC(K,IY)   -   2.0* BEEC(K,IY))
      FMC(K,IY)=FMC(K,IY) * 3.14159265
      FPC(K,IY)=FPC(K,IY) * 3.14159265
   20 CONTINUE
C
C **   DEBUG PRINT   **
C
      IF (IDG.NE.99) GO TC 21
      CALL DUGPR (3)
   21 QCC(IYY)=C.
      DO 24 K=1,12
C
C **   LINE AND CROSS TERM FLUX DIVERGENCE CALCULATION   **
C
   24 QCC(IYY)=QCC(IYY)   +   QCCP(K)
      IF (LINES.EQ.C) GC TO 1614
```

```
C
C **   INTEGRATION FROM 1 TO IY  **
C
      IF (IY.EQ.1) GO TO 68
      DO 65 J=1,9
      DO 66 L=1,IY
      WIM=0.
      SUM1=0.
      SUM2=0.
      DO 67 M=1,4
      DIF=ETAM(J,M,IY)  -  ETAM(J,M,L)
      DIFSBM =     SBM(J,M,IY)-SBM(J,M,L)
      IF(ABS(DIFSBM).LT.1.E-10)  DIFSBM = 1.E-10
      BETAM=DIF / ( DIFSBM                  )  *  3.14159265
      IF (L.EQ.IY) BETAM=GGM(J,M,L)
      IF(ABS(DIF).GT.1.E-10) GO TO 9001
      TM = 1.E-10
      GO TO 9002
 9001 CONTINUE
      TM=DIF/2.0/BETAM**2
 9002 RRM=DIF/2.0/GGM(J,M,IY)**2
      WWM=6.2831853 * WN(J,M) * BETAM * GAMMA(TM) * TM
      SUM1=SUM1  +  GAMMA(TM) * WN(J,M) * SSM(J,M,IY)
      SUM2=SUM2  +  XLAMB(RRM) * WN(J,M) * SSM(J,M,IY)
   67 WIM=WIM  +  WWM
      ALPHAM=WIM/DJ(J)
C
C **   OVERLAPPING LINE CALCULATIONS  **
C
C
C **   GROUP EQUIVALENT WIDTHS  (EQ.88)  **
C
      WMM(J,L)=DJ(J) * PHI1(ALPHAM) * EXP(TAUL(J,L)-TAUL(J,IY))
C
C **   GROUP GAMMA -- LINE TRANSPORT FUNCTION (EQ.92)  **
C
```

```
      GMM(J,L)=PHI2(ALPHAM) * SUM1
C
C **    MINUS EMISSIVITY FUNCTION FOR LINES (EQ.47)   **
C
      EEM(J,L)=1.0  -  EXP(TAUL(J,L)-TAUL(J,IY))
   66 XLMM(J,L)=PHI2(ALPHAM) * SUM2
   65 CONTINUE
      IF (IDG.EQ.99) CALL BUGPR(1)
      IF (IDG.EQ.99) CALL BUGPR (4)
   68 IF (IY.EQ.NES) GO TO 72
C
C **    INTEGRATION FROM IY TO NES   **
C
      DO 69 J=1,9
      DO 70 L=IY,NES
      WIP=0.
      SUM1=0.
      SUM2=0.
      DO 71 M=1,4
      DIF=ETAM(J,M,L)  -  ETAM(J,M,IY)
      DIFSBM =     SBM(J,M,L)-SBM(J,M,IY)
      IF(ABS(DIFSBM).LT.1.E-10)  DIFSBM = 1.E-10
      BETAP=DIF / ( DIFSBM                    )  *  3.14159265
      IF (L.EQ.IY) BETAP=GGM(J,M,L)
      IF(ABS(DIF).GT.1.E-10) GO TO 9003
      TP = 1.E-10
      GO TO 9004
 9003 CONTINUE
      TP=DIF/2.0/BETAP**2
 9004 RRP=DIF/2.0/GGM(J,M,IY)**2
      WWP=6.2831853 * WN(J,M) * BETAP * GAMMA(TP) * TP
      SUM1=SUM1  +  GAMMA(TP) * WN(J,M) * SSM(J,M,IY)
      SUM2=SUM2  +  XLAMB(RRP) * WN(J,M) * SSM(J,M,IY)
   71 WIP=WIP+WWP
      ALPHAP=WIP/DJ(J)
      WPP(J,L)=DJ(J) * PHI1(ALPHAP) * EXP(TAUL(J,IY)-TAUL(J,L))
```

```
      GPP(J,L)=PHI2(ALPHAP) * SUM1
C
C **   POSITIVE EMISSIVITY FUNCTICN FOR LINES (EQ.47)   **
C
      EEP(J,L)=1.C  -  EXP(TAUL(J,IY)-TAUL(J,L))
   70 XLPP(J,L)=PHI2(ALPHAP) * SUM2
   69 CONTINUE
C
C **   DEBUG PRINT  **
      IF (IDG.EQ.99) CALL BUGPR (5)
C
   72 DO 80 J=1,9
      ASM1=0.
      ASM2=0.
      FM(J,IY)=C.
      IF (IY.EQ.1) GO TO 81
      DO 82 L=2,IY
      FM(J,IY)=FM(J,IY)  -  (WMM(J,L)-WMM(J,L-1))
     1       *(BEEL(J,L-1)+BEEL(J,L)) * 1.5707963
      IF (L.EQ.IY) GO TO 82
      ASM1=ASM1  -  (EEM(J,L)-EEM(J,L-1))
     1       * (BEEL(J,L-1) * XLMM(J,L-1) + BEEL(J,L) * XLMM(J,L))/2.
      ASM2=ASM2  -  (XLMM(J,L)-XLMM(J,L-1))
     1       * (BEEL(J,L-1) * EXP(TAUL(J,L-1)-TAUL(J,IY)) + BEEL(J,L)
     2       * EXP(TAUL(J,L)-TAUL(J,IY)))/2.0
   82 CONTINUE
   81 ASP1=0.
      ASP2=0.
      IYP=IY+1
      IF (IY.EQ.NES) GO TO 83
      DO 84 L=IYP,NES
      FP(J,IY)=FP(J,IY)  +  (WPP(J,L)-WPP(J,L-1))
     1       * (BEEL(J,L-1)+BEEL(J,L)) * 1.5707963
      IF (L.EQ.IYP) GO TC 84
      ASP1=ASP1  +  (EEP(J,L)-EEP(J,L-1))
     1       * (BEEL(J,L-1) * XLPP(J,L-1) + BEEL(J,L) * XLPP(J,L))/2.0
```

```
      ASP2=ASP2  +  (XLPP(J,L)-XLPP(J,L-1)) *
     1      (BEEL(J,L-1) * EXP(TAUL(J,IY)-TAUL(J,L-1))  +  BEEL(J,L)
     2      * EXP(TAUL(J,IY)-TAUL(J,L)))/2.0
   84 CONTINUE
   83 QLCP(J)=2.0 * FMUL(J,IY) * (FM(J,IY)+FP(J,IY))
      SUMS=1.0
      SUMT=0.
      DO 86 M=1,4
   86 SUMT=SUMT  +  SSM(J,M,IY) * WN(J,M)
      ATM1=0.
      IF (IY.NE.1) ATM1=(BEEL(J,IY-1)+BEEL(J,IY)) /2.0 * EEM(J,IY-1)
     1      * XLMM(J,IY-1)
      ATP1=0.
      IF(IY.NE.NES) ATP1=(BEEL(J,IY+1)+BEEL(J,IY))/2.0 * EEP(J,IY+1)
     1      * XLPP(J,IY+1)
      QCLP(J)=6.2831853  * SUMS * (ASM1+ASP1+ATM1+ATP1)
      IF (IY.EQ.1) ATM2=-BEEL(J,IY) * SUMT
      IF (IY.NE.1) ATM2=(BEEL(J,IY-1)-BEEL(J,IY))  *  GMM(J,IY-1)
     1      -  BEEL(J,IY-1) * XLMM(J,IY-1)
      IF (IY.EQ.NES) ATP2=-BEEL(J,IY) * SUMT
      IF (IY.NE.NES)ATP2=(BEEL(J,IY+1)-BEEL(J,IY))  * GPP(J,IY+1)
     1      -  BEEL(J,IY+1) * XLPP(J,IY+1)
      QLLP(J)=6.2831853 * SUMS*(-ASM2-ASP2+ATM2+ATP2)
   80 CONTINUE
      QCL(IYY)=0.
      QLC(IYY)=0.
      QLL(IYY)=0.
      DO 85 J=1,9
      QCL(IYY)=QCL(IYY)  +  QCLP(J)
      QLC(IYY)=QLC(IYY)  +  QLCP(J)
   85 QLL(IYY)=QLL(IYY)  +  QLLP(J)
 1614 CONTINUE
      DQN(IYY)=-(QCC(IYY)+QCL(IYY)+QLC(IYY)+QLL(IYY))
C
C **   DEBUG PRINT  **
C
```

```
      IF (IDG.EQ.0) GO TO 49                                             TRAN5770
      CALL BUGPR(6)                                                      TRAN5780
   49 CONTINUE                                                           TRAN5790
      IEZ=IEZ-1                                                          TRAN5800
      DQ(1)=DQN(1)                                                       TRAN5810
      L=2                                                                TRAN5820
      DO 1 N=2,NES                                                       TRAN5830
      DO 2 I=2,IEZ                                                       TRAN5840
      NP=I                                                               TRAN5850
      IF (ETZ(I).GT.ETA(N)) GO TO 3                                      TRAN5860
    2 CONTINUE                                                           TRAN5870
    3 NN=NP-1                                                            TRAN5880
      AA=0.0                                                             TRAN5890
      ZB=(DQN(NN)-DQN(NP)) / (ETZ(NN)-ETZ(NP))                           TRAN5900
      CC=DQN(NN)  -  ZB * ETZ(NN)                                        TRAN5910
      DQ(N)=AA * ETA(N)**2  +  ZB * ETA(N)  +  CC                        TRAN5920
      GO TO 1                                                            TRAN5930
    4 DQ(N)=DQN(NN)                                                      TRAN5940
    1 CONTINUE                                                           TRAN5950
      RETURN                                                             TRAN5960
      END                                                                TRAN5970
```

```
      SUBROUTINE ZP(T1,SUMN,SUMO,SUMH,SUMC)
C
C     **  FRACTIONAL POPULATION STATES FOR N, O, H, C  **
C
      COMMON /ZPI/ ZPO(6), ZPN(6),ZPH(2),  ZPC(7)
      ZPH(1)=2.0/SUMH
      ZPH(2)=8.0 * EXP(-10.20/T1)/SUMH
      ZPC(1)=9.0/SUMC
      ZPC(2)=5.0 * EXP(-1.264/T1)/SUMC
      ZPC(3)=EXP(-2.684/T1)/SUMC
      ZPC(4)=5.0 * EXP(-4.183/T1)/SUMC
      ZPC(5)=12.0 * EXP(-7.532/T1)/SUMC
      ZPC(6)=36.0*EXP(-8.722/T1)/SUMC
      ZPC(7)=60.0 * EXP(-9.724/T1)/SUMC
      ZPN(1)=4.0/SUMN
      ZPN(2)=10.0* EXP(-2.384/T1)/SUMN
      ZPN(3)=6.0 * EXP(-3.576/T1)/SUMN
      ZPN(4)=18.0 * EXP(-10.452/T1)/SUMN
      ZPN(5)=54.0 * EXP(-11.877/T1)/SUMN
      ZPN(6)=90.0 * EXP(-13.002/T1)/SUMN
      ZPO(1)=9.0/SUMO
      ZPO(2)=5.0 * EXP(-1.967/T1)/SUMO
      ZPO(3)=EXP(-4.188/T1)/SUMO
      ZPO(4)=8.0 * EXP(-9.283/T1)/SUMO
      ZPO(5)=24.0 * EXP(-10.830/T1)/SUMO
      ZPO(6)=40.0 * EXP(-12.077/T1)/SUMO
C
      RETURN
      END
```

```
      SUBROUTINE ZHV(HV,ZO,ZN,ZI,ZC)
C
C
C  **  THIS SUBROUTINE CALCULATES THE QUANTUM MECHANICAL CORRECTION
C          FACTORS GIVEN A FREQUENCY (HV) **
C
      X= HV
      X2 =X*X
      X3 =X2*X
      X4 =X3*X
      X5 =X4*X
      X6 =X5*X
      X7 =X6*X
      IF (X -9.82) 1,1,2
    1 ZO = .9999795             -.3155480*X           +2.824548 E-02*X2
     1      +6.677328 E-03*X3   -3.644585 E-03*X4     +8.058070 E-04*X5
     2      -7.708637 E-05*X6   +2.668133 E-06*X7
      GO TO 3
    2 ZO = (X/9.82)**3
    3 IF (X -8.35) 4,4,5
    4 ZN = 1.000148             - .4183535 *X         + .1680359 *X2
     1      -9.779458 E-02*X3   +3.354635 E-02*X4     -5.609353 E-03*X5
     2      +4.515535E-04*X6    -1.403585 E-05*X7
      GO TO 6
    5 ZN = (X/8.35)**3
    6 Y = X/4.0
      IF (Y-6.6) 9,9,10
    9 Y2 =Y*Y
      Y3 =Y2*Y
      Y4 =Y3*Y
      Y5 =Y4*Y
      Y6 =Y5*Y
      Y7 =Y6*Y
      ZI = 1.000379             - .2964767 *Y         +7.505242 E-02*Y2
     1      -1.702948E-02*Y3    +3.279554 E-03*Y4     -2.128469 E-04*Y5
      GO TO 11
```

```
10    ZI = (Y/6.6)**3                                                                    ZHV( 370
11    IF (X-7.37) 12,12,13                                                               ZHV( 380
12    ZC =   .9974367               - .4341812 *X          +8.531314 E-02*X2             ZHV( 390
     1     -1.393917 E-02*X3        +4.038545 E-03*X4      -5.426425 E-04*X5             ZHV( 400
     2     +2.812126 E-05*X6        -3.883530 E-07*X7                                    ZHV( 410
      GO TO 14                                                                           ZHV( 420
13    ZC = (X/7.37)**3                                                                   ZHV( 430
14    RETURN                                                                             ZHV( 440
      END                                                                                ZHV( 450
```

```
      SUBROUTINE TRANS2
      COMMON /SFLUX/ QRI(3),QRR
      COMMON /XY/  XI, DXI, ETA( 5),  DETA
      COMMON /FRSTRM/     U INF,     RINF,      UINF2,     XL,   RE,   LXI,
     1                    ITM,       ITG,       NES
      COMMON /TRN/ YD( 5),NUT( 5), FMC(12, 5), FPC(12, 5),
     1             FM(9, 5), FP(9, 5), LINES
      COMMON /FINV/ NHVL,NIHVC,FHVC(12),CJ(9),HVJ(9),ZKZ
      COMMON /TEST/ETZ( 5),IEZ
      COMMON /NUMDEN/ SNDC2( 5), SNDN2( 5), SNDO( 5), SNDN( 5),
     1                                       SNDE( 5), SNDC( 5),
     2                SNDH( 5), SNDC2( 5), SNDH2( 5), SNDCO( 5),
     3                SNDC3( 5)
      COMMON /SPEC/     XMCL
      COMMON /MAIN1/ NXI,  MAXG,  MAXM,  MAXS,  IDG,      MCONV,
     1  GCONV, SCONV
      COMMON /OPT/ ITYPE , PDK ,IPAGE,THETA,PHI,EPS
      DIMENSION ETOUT(3)
      NETA=NES
      ETOUT(1)=0.0
      ETOUT(2)=0.5
      ETOUT(3)=1.0
      NOUT=3
C
C  OUTPUT FLUX
C
      IF(IDG.EQ.0)GO TO 10
      WRITE (6,600)
      WRITE (6,603) (ETA(I),SNDC2(I),SNDN2(I),SNDO(I),SNDN(I),
     1                     SNDE(I), SNDH(I), I=1,NETA)
      WRITE (6,602)
      WRITE (6,601) (ETA(I),SNDC(I),SNDC2(I),SNDH2(I),SNDCO(I),SNDC3(I),
     1                                         I=1,NETA)
C **   CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX **
C
      WRITE(6,20)IPAGE
```

```
   20 FORMAT(1H1,74X,'PAGE NO.',I5)
      WRITE (6,4103)
   10 CONTINUE
      DO 8040 K=1,NCUT
      DO 8041 LK=1,NES
      NUT(K)=LK
      IF (ABS(ETOUT(K)-ETA(LK)) - 1.0E-05) 8040,8040,8041
 8041 CONTINUE
 8040 CONTINUE
      L1=NUT(1)
      L2=NUT(2)
      L3=NUT(3)
      IF(IDG.EQ.0)GO TO 30
      WRITE (6,8037)(ETOUT(IL),IL=1,3)
   30 CONTINUE
      FM1=0.0
      FP1=0.0
      FM2=0.0
      FP2=0.0
      FM3=0.0
      FP3=0.0
      DO 4104 KL=1,NIHVC
      IF(IDG.EQ.0)GO TO 40
      WRITE (6,8042) KL,    FHVC(KL),    FMC(KL,L1),    FPC(KL,L1),
     1              FMC(KL,L2),    FPC(KL,L2),    FMC(KL,L3),    FPC(KL,L3)
   40 CONTINUE
      FM1=FM1    +   FMC(KL,L1)
      FP1=FP1    +   FPC(KL,L1)
      FM2=FM2    +   FMC(KL,L2)
      FP2=FP2    +   FPC(KL,L2)
      FM3=FM3    +   FMC(KL,L3)
      FP3=FP3    +   FPC(KL,L3)
 4104 CONTINUE
      IF(IDG.EQ.0)GO TO 50
      WRITE (6,8045) FM1,    FP1,    FM2,    FP2,    FM3,    FP3
   50 CONTINUE
```

```
      QRI(1)=FM1+FP1                                                    TRAN 730
      QRI(2)=FM2+FP2                                                    TRAN 740
      CRI(3)=FM3+FP3                                                    TRAN 750
C                                                                       TRAN 760
C **   LINE      CONTRIBUTION TO THE SPECTRAL FLUX **                   TRAN 770
C                                                                       TRAN 780
      IF (LINES.EQ.C) RETURN                                            TRAN 790
      IF(IDG.EQ.0)GO TO 60                                              TRAN 800
      WRITE (6.8C35)                                                    TRAN 810
      WRITE (6.8C37) (ETCUT(IL).IL=1.3)                                 TRAN 820
   60 CONTINUE                                                          TRAN 830
      FM1=C.C                                                           TRAN 840
      FP1=C.C                                                           TRAN 850
      FM2=C.0                                                           TRAN 860
      FP2=0.C                                                           TRAN 870
      FM3=C.C                                                           TRAN 880
      FP3=C.C                                                           TRAN 890
C                                                                       TRAN 900
C **   TOTAL FLUX CALCULATION   **                                      TRAN 910
C                                                                       TRAN 920
      DO 8C43 KL=1.NHVL                                                 TRAN 930
      IF(ICG.EQ.C)GO TO 70                                              TRAN 94C
      WRITE (6.8C42) KL.   HVJ(KL).   FM(KL.L1).   FP(KL.L1).           TRAN 950
     1             FM(KL.L2).   FP(KL.L2).   FM(KL.L3).   FP(KL.L3)     TRAN 96C
   70 CONTINUE                                                          TRAN 970
      FM1=FM1   +  FM(KL.L1)                                            TRAN 98C
      FP1=FP1   +  FP(KL.L1)                                            TRAN 990
      FM2=FM2   +  FM(KL.L2)                                            TRAN1000
      FP2=FP2   +  FP(KL.L2)                                            TRAN101C
      FM3=FM3   +  FM(KL.L3)                                            TRAN1C2C
      FP3=FP3   +  FP(KL.L3)                                            TRAN1C30
 8043 CONTINUE                                                          TRAN1040
      IF(ICG.EQ.0)GO TO 8C                                              TRAN1050
      WRITE (6.8045) FM1.   FP1.   FM2.   FP2.   FM3.   FP3             TRAN1060
   80 CONTINUE                                                          TRAN1C70
      GRI(1)=QRI(1)   +  FM1   +  FP1                                   TRAN1080
```

```
      QRI(2)=QRI(2)   +   FM2   +   FP2
      QRI(3)=QRI(3)   +   FM3   +   FP3
C
  600 FORMAT (1H1,33HNUMBER DENSITIES   (PARTICLES/CM3) ///5X,3HETA,12X,
     1        2HC2,11X,2HN2,11X,1HC,12X,1HN,12X,                    2HE-,
     2        12X,1HH //)
  601 FORMAT (1P6E13.4)
  602 FORMAT (1H1,33HNUMBER DENSITIES   (PARTICLES/CM3) ///5X,3HETA,12X,
     1        1HC,12X,2HC2,11X,2HH2,11X,2HCC,11X,2HC3///)
  603 FORMAT (1P7E13.4)
 4103 FORMAT (44H CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX)
 8035 FORMAT (39HOLINE CONTRIBUTION TO THE SPECTRAL FLUX)
 8037 FORMAT (/22X,5HETA =F7.3,13X,5HETA =F7.3,13X,5HETA =F7.3//3X,1HI,
     1 3X,3HHNU,8X,6HQMINUS,7X,5HQPLUS,8X,6HQMINUS,7X,5HQPLUS,8X,
     2 6HQMINUS,7X,5HQPLUS/)
 8042 FORMAT (I4,F8.3,1P8E13.3)
 8045 FORMAT (12HOTOTAL FLUX ,1P8E13.3)
      RETURN
      END
```

```
      SUBROUTINE BUGPR (IDGSW)
C
C  **  THIS SUBROUTINE CONTAINS DEBUG PRINT OPTIONS WHICH
C      PROVIDES INTERMEDIATE PRINT FROM SUBROUTINE TRANS   **
C
      COMMON /FRSTRM/    U INF,     RINF,      UINF2,     XL,   RE,   LXI,
     1                   ITM,       ITG,       NES
      COMMON /XY/  XI, DXI, ETA( 5),  DETA
      COMMON /TRN/ YD( 5),NUT( 5), FMC(12, 5), FPC(12, 5),
     1              FM(9, 5),  FP(9, 5), LINES
      COMMON /DEBUG/ QLC( 5), QCL( 5), CLL( 5), DGN( 5), QCC( 5),
     1              BEEC(12, 5),   FMUC(12, 5),   EM(12, 5),
     2              EP(12, 5),     TAUC(12, 5),   BEEL(9, 5),
     3              QCCP(12),      WMM(9, 5),     GMM(9, 5),
     4              EEM(9, 5),     XLMM(9, 5),    QLCP(9),
     5              QCLP(9),       CLLP(9),       DELTA,     IY,    IYY,
     6              WPP(9, 5),     GPP(9, 5),     EEP(9, 5),
     7              XLFP(9, 5),    FG(9,4),       GP(9,4),
     8              WN(9,4),       FMUL(9, 5),    SSM(9,4, 5),
     9              GGM(9,4, 5),   ETAM(9,4, 5),  SBM(9,4, 5),
     A              TAUL(9, 5)
       GO TO (10,20,30,40,50,60,70), IDGSW
   10               WRITE (6,194)
  194 FORMAT (1H1)
      RETURN
   20 WRITE (6,7182) DELTA
 7182 FORMAT (7HCDELTA=1PE14.7,3H CM)
      RETURN
   30 WRITE (6,190) IY,    YD(IY)
  190 FORMAT (4H1IY=I3,2X,3HYD=1PE12.5//2X,1HK,2X,1HL,7X,3HETA,13X,2HYD,
     1 13X,2HMU,11X,3HTAU,14X,1HE,11X,3HBEE//)
      DO 22 K=1,12
      IF (IY.EQ.1) GO TO 23
      WRITE(6,191) (K,    L,    ETA(L),    YC(L),    FMUC(K,L),    TAUC(K,L),
     1               EM(K,L),   BEEC(K,L),   L=1,IY)
  191 FORMAT (2I3,1P6E15.5)
```

```
      WRITE (6,192)
  192 FORMAT (//)
   23 IF (IY.EQ.NES) GO TO 22
      WRITE (6,191) (K,   L,   ETA(L),   YD(L),   FMUC(K,L),
     1             TAUC(K,L),   EP(K,L),   BEEC(K,L),   L=IY,NES)
   22 WRITE (6,193) FMC(K,IY),   FPC(K,IY),   QCCP(K)
  193 FORMAT (5HCFIM=1PE12.5 ,2X,4HFIP=E12.5,2X,5HQCCP=E12.5)
      RETURN
   40                  WRITE (6,195) IY,   YD(IY),   ((J,   L,   YD(L),
     1             WMM(J,L),   GMM(J,L),   XLMM(J,L),   EEM(J,L),
     2             BEEL(J,L),   L=1,IY),   J=1,9)
  195 FORMAT (4HCIY=I3,2X,3HYY=1PE12.5//2X,1HJ,2X,1HL,7X,2HYD,12X,3HWMM,
     1 12X,3HGMM,11X,4HXLMM,13X,3HEEM,13X,3HBEE//(2I3,6E16.5))
      RETURN
   50                  WRITE (6,196) IY,   YD(IY),   ((J,   L,   YD(L),
     1          WPP(J,L),   GPP(J,L),   XLPP(J,L),   EEP(J,L),
     2          BEEL(J,L),   L=IY,NES),   J=1,9)
  196 FORMAT (4HCIY=I3,2X,3HYY=1PE12.5//2X,1HJ,2X,1HL,7X,2HYD,13X,3HWPP,
     1 2X,3HGPP,11X,4HXLPP,13X,3HEEP,13X,3HBEE//(2I3,6E16.5))
      RETURN
   60 WRITE (6,198) IY,   ETA(IY),   YD(IY)
  198 FORMAT (4HCIY=I3,2X,4HETA=1PE12.5,2X,3HYY=E12.5//2X,1HJ,5X,3HQCC,
     1 11X,3HFMC,11X,3HFPC,11X,3HQCL,11X,3HQLC,11X,3HQLL,12X,2HFM,12X,
     2 2HFP,11X,3HDQN//)
      WRITE (6,199) (J,   QCCP(J),   FMC(J,IY),   FPC(J,IY),
     1             QCLP(J),   QLCP(J),   QLLP(J),   FM(J,IY),FP(J,IY),
     2             J=1,9)
  199 FORMAT (I3,1P8E14.5)
      WRITE (6,8069) (J,   QCCP(J),   FMC(J,IY),   FPC(J,IY),   J=10,12)
 8069 FORMAT (I3,1P3E14.5)
      WRITE (6,200) QCC(IYY),   QCL(IYY),   QLC(IYY),   QLL(IYY),
     1             DQN(IYY)
  200 FORMAT (1H0,2X,1PE14.5,28X,3E14.5,28X,E14.5)
      RETURN
   70 WRITE (6,197) L,   ETA(L),   YD(L),   ((J,   M,   WN(J,M),
     1             FG(J,M),   GP(J,M),   FMUL(J,L),   TAUL(J,L),
```

```
    2             SSM(J,M,L),    GGM(J,N,L),    ETAM(J,M,L),    SBM(J,M,L),BUGP 730
    3             N=1,4),J=1,9)                                             BUGP 740
197 FORMAT (3HOL=I3,2X,4HETA=1PE12.5,2X,3HYD=E12.5//2X,1HJ,2X,1HM,7X,  BUGP 750
  1 1HN,13X,1HF,13X,1HG,11X,3HFNU,11X,3HTAU,11X,3HSSM,11X,3HGGM,10X,   BUGP 760
  2 4HETAM,11X,3HSBM//(2I3,9E14.5))                                      BUGP 770
    RETURN                                                               BUGP 780
    END                                                                  BUGP 790
```

APPENDIX E

References

E.1 Hansen, C. F., "Approximations for the Thermodynamic Properties of High Temperature Air," NASA TR R-50, 1959.

E.2 Livingston, F. and J. Williard, "Planetary Entry Body Heating Rate Measurements in Air and Venus Atmospheric Gas up to 15000°K," AIAA J., 9, No. 3, March 1971.

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